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THE BULLETIN

of the

AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS

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BULLETIN

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AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS

JUNE, 1928

GENETIC RELATIONSHIP OF OIL RESERVOIRS TO SHORE-LINE DEPOSITS[1]

CHARLES BREWER, JR.[2]
Bartlesville, Oklahoma

ABSTRACT

The local and lenticular sands of many oil fields have undoubtedly originated as shore-line features (bars, hooks, and spits), in the seas of the geologic past.

An approximate genetic classification has been made of the more important types of these sand bodies, and the processes leading to their deposition and preservation in sedimentary strata have been considered in some detail.

From this study several conclusions have been drawn.

Offshore submarine bars are preserved as elongate, pod-shaped sand bodies of coarse material in offshore sediments. Their characteristics and stratigraphic relations are moderately favorable to oil accumulation.

Exceptional conditions of subsidence and sedimentation are necessary in order to bring about the preservation of barrier beaches within marine sediments. They would probably form straight, narrow deposits of coarse, well-sorted sand, exhibiting an almost lenticular cross-section, convex side upward. Their associated beds would be favorable to oil accumulation.

Many hooks, spits, bars, and tombolos, built out into deep water, hence below the depth of wave action, are preserved as marine sediments. Many local, lenticular oil sands probably originate as one or another of these forms. They are likely to vary greatly in shape and size, but in general their characteristics and stratigraphic relations fit them admirably to serve as oil reservoirs.

INTRODUCTION

Many oil fields produce all or a part of their oil from lenticular and discontinuous sandstone reservoirs, and the successful development of this type of oil pool without considerable blind groping and drilling of dry holes presents a difficult problem to a petroleum geologist. Under

[1]Manuscript received by the editor, February 23, 1928.

[2]Geological department, Indian Territory Illuminating Oil Company.

these conditions, structure is relatively unimportant, and commercial production is controlled by the shape, extent, area, and thickness of the lenses. These factors, in turn, are generally the result of conditions of sedimentation at the time of deposition and burial of the sand bodies.[1]

A facies of deposition in which the conditions of sedimentation are favorable to the formation of lenticular sand bodies close to suitable organic source beds is found in the zone of shore-line deposition, where bars, spits, and hooks are built up by wave and current action. A study therefore of the complex factors governing the deposition and preservation of the different types of sand bodies within this zone, and an analysis of their characteristics and value as oil reservoirs on final preservation in a sedimentary series, should be of aid in the interpretation of the stratigraphic problems of many oil fields. It is hoped that this paper may be a step in that direction.

The material in this article originally formed a more detailed study as part of a master's thesis at the University of Pittsburgh. The writer wishes to make acknowledgment to Professor R. E. Somers of the geological department for his aid in planning and developing the original thesis, and to Professor Roswell H. Johnson of the oil and gas department for his constructive criticism and many suggestions. He likewise wishes to thank Professor P. E. Raymond of the paleontology department and Professor Kirtley F. Mather of the geological department of Harvard University for their aid in re-working the original material.

METHOD OF TREATMENT

A genetic classification of the types of shore-line sand bodies has been made as follows:

1. Offshore submarine bars.
2. Offshore barrier beaches.
3. Sand bodies built out into deep water, including hooks, spits, tombolos, and cuspate forelands.

Before taking up the subject of mode of origin and preservation there is one fundamental principle of sedimentation which one should have clearly in mind in order to understand the factors in the preservation of lenticular sand bodies. This is known as the "profile of equilibrium."[2] It may be defined as a potential base level of the sea bottom

[1]Sand body is a term coined by Johnson and Huntley in their *Principles of Oil and Gas Production* to designate any "continuous mass of sand or sandstone." It will be so used throughout this paper.

[2]N. M. Fenneman, "Development of the Profile of Equilibrium of the Subaqueous Shore Terrace," *Journal of Geology*, Vol. 10 (1902).

at which there is an exact balance between deposition and erosion. It varies, of course, with existing conditions, such as power of the waves, amount of sediment being supplied by rivers, and elevation of land. It is analogous to the base level established by rivers in the old-age stage of the erosion cycle when aggradation and degradation are in exact balance.

Where the sea bottom is below the profile of equilibrium (for example, on a steep shore subsiding at a fairly rapid rate) deposition takes place. If subsidence should cease, sediments would build up until they reached the profile of equilibrium and *no farther*. If the land remained stationary the sediments supplied to the sea would become less, thereby lowering the profile of equilibrium below the sea bottom and causing wave erosion to remove the previously deposited sediments.

The ultimate base level of wave erosion on an open coast is about 600 feet:[1] in other words, if static conditions should continue throughout a long enough period of time, the offshore profile (or sea bottom) would finally be lowered to a depth of 600 feet below sea-level. Under ordinary conditions of offshore sedimentation, such as exist to-day off the Atlantic and Gulf coasts of North America, the profile of equilibrium is far above this depth, and in the shallow epi-continental seas which were the basins of deposition for most of our oil-producing strata, bottom scour by waves was far less effective than on coasts exposed to a sweep of thousands of miles of deep ocean.

It should be noticed that no deposits except those below the depth of wave action may be considered as permanent. Of course, in case of a steadily subsiding land mass, sedimentation will never quite catch up to the profile of equilibrium, and near-shore sediments will be carried into deeper water and eventually buried beneath layers of mud at a depth below ultimate wave base.

This principle is of great importance.

OFFSHORE SUBMARINE BARS

Many lenticular sand bodies which are considerably elongate must have originated as offshore submarine bars. Waves break when the depth of water becomes equal to, or less than, their own height. In breaking they tend to pile up the bottom material in the form of a sand bar. Sorting action washes away the fine material and leaves the coarse sand. Thus, on a gently-shelving shore, at times of great storms, bars will be thrown up at depths not ordinarily affected in this way by wave

[1] J. Barrell, "Rhythms and Measurements of Geologic Time," *Bulletin Geol. Soc. Amer.*, Vol. 28, pp. 777-79.

action. In most cases sand bars built up in this way are probably destroyed by subsequent storms, when conditions such as direction of wind and currents vary enough to cause bottom scour instead of deposition. However, if the bottom is subsiding or sedimentation is rapid, these bars may be carried below the profile of equilibrium and preserved as pod-shaped bodies of coarse sand within finer sediments. Many coarse elongate sand bodies occurring within larger marine sand formations undoubtedly had their origin in this way. Where the main formation is very fine-grained, as many are, porosities high enough to yield oil will occur in these lenses and they thus become lenticular reservoirs.

BARRIER BEACHES

The manner of burial and preservation of barrier beaches and sand dunes of the type found off the south Atlantic and Gulf coasts of North America presents a problem deserving considerable attention, for it is one about which there is much misconception. The common view seems to be that a rising sea will encroach over a dune-capped bar and bury it, undisturbed in its original form, under a cover of offshore sediments. A study of Figure 1, after D. W. Johnson, shows the impossibility of any such process. Even under static conditions of land and sea the bar is ordinarily doomed to destruction. Waves are constantly excavating the shore face of the bar and piling back on the beach some of the coarse material not transported out to deep water. The entire barrier beach thus migrates landward, and no deposits are preserved which previously existed above the profile of equilibrium of the final stage (Fig. 1, *H*).

A barrier beach is characteristic of a generally emerging coast line. Emergence, however, leads to destruction rather than preservation of such deposits, for with a falling sea-level there is no protective cover of sediments deposited over the barrier beach, and it will ultimately either be washed away by stream erosion on the land if emergence continues, or scoured out by the waves if submergence sets in and the sea advances inland again.

Barrier beaches may form on submerging as well as emerging coasts, however, provided the transgressed land surface is low enough to furnish the requisite profile. Furthermore, it may be preserved under such conditions if some agency keeps the shore prograded until subsidence has carried a part of the resultant composite bar and lagoonal formations below the profile of equilibrium which would be established on the final encroachment of the sea. This could be brought about by

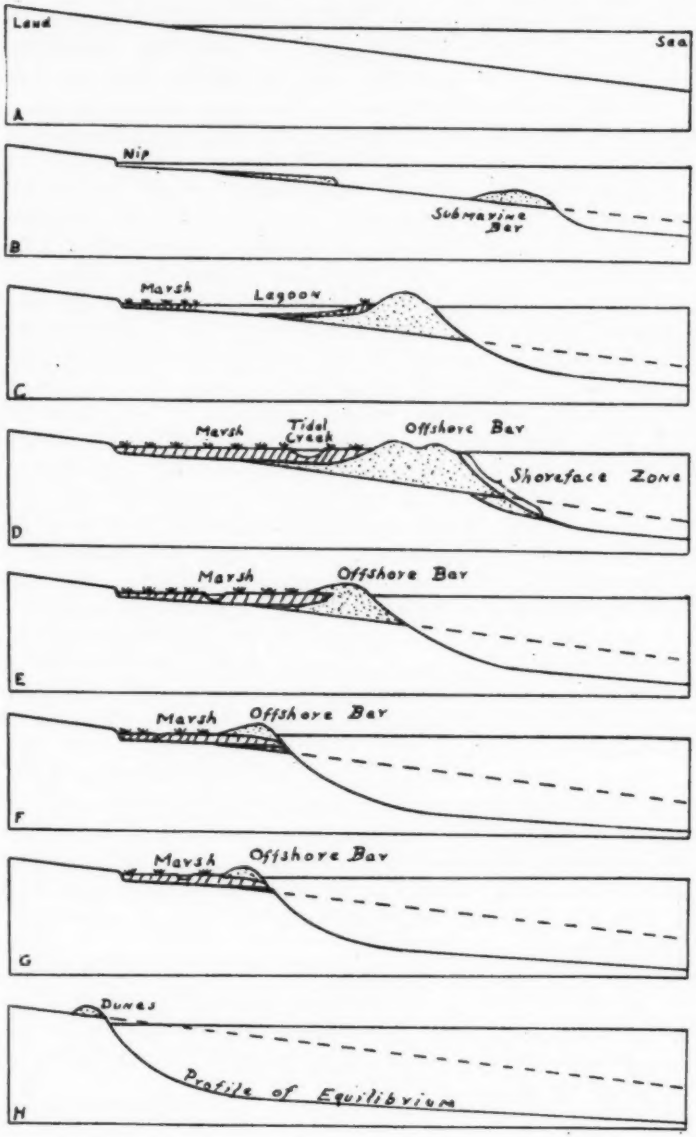

FIG. 1.—Stages in the normal history of a barrier beach (modified after D. W. Johnson).

the longshore transportation of debris resulting from diagonal wave attack (beach drifting of D. W. Johnson), or other types of longshore currents which tend to run stronger in one direction than the other. Wave attack on a sandstone coast or a large river entering the sea to windward of the site of deposition might furnish a sufficient supply of coarse detritus.

Figure 2 is intended to show the successive stages which would ultimately lead to the preservation of lenticular barrier-beach deposits. The profiles from the seaward edge of the lagoon to the east end of the section are generalized profiles taken from United States Coast and Geodetic Survey charts. Prior to *A* an emerging coast line has been postulated. This accounts for the inner bar *b1* left behind when the depth offshore became so shallow that the outer bar *b2* was thrown up.

Between *A* and *B* there has been a subsidence of 60 feet, accompanied by a prograding of the shore. A succession of beach ridges and dunes is thus built seaward overlapping onto the finer-grained offshore deposits. It is assumed that subsidence and lagoonal sedimentation keep pace with each other, so that between *A* and *B* there has been approximately 60 feet of muds deposited in this zone. The original bar *b1* is thus completely buried under a cover of lagoonal sediments which are likewise encroaching over the landward side of bar *b2*. The inner margin of the lagoon has migrated inland, so that the latter is considerably wider in sketch *B* than in *A*. It is likely that flood-plain sedimentation on the land will counteract this encroachment somewhat, for on extremely low coastal plains, as in the vicinity of Norfolk, Virginia, a 20-foot subsidence would be enough to bring the sea an equal number of miles inland.

Sketch *C* shows the effects of further subsidence on this large beach-ridge deposit. Wave attack on the shore face of the bar has pushed it inland to its new position, the dotted portion indicating the part of the sand and lagoonal deposits which existed in the immediately preceding stage thus destroyed. Notice that the original bar *b1* and a portion of the large sand-dune deposits which existed in *B* remain undestroyed by wave action.

If subsidence continues at a fairly rapid and even rate, bottom scour will shortly give place to deposition, so that although the shore line continues to migrate inland, these deposits will be carried below the profile of equilibrium and buried under a cover of offshore sediments as shown in sketch *D*.

The outer edge of a large delta is a favorable environment for barrier-beach formation, for the subaqueous plain is gently sloping, causing waves to break at a long distance from shore. Barrier beaches

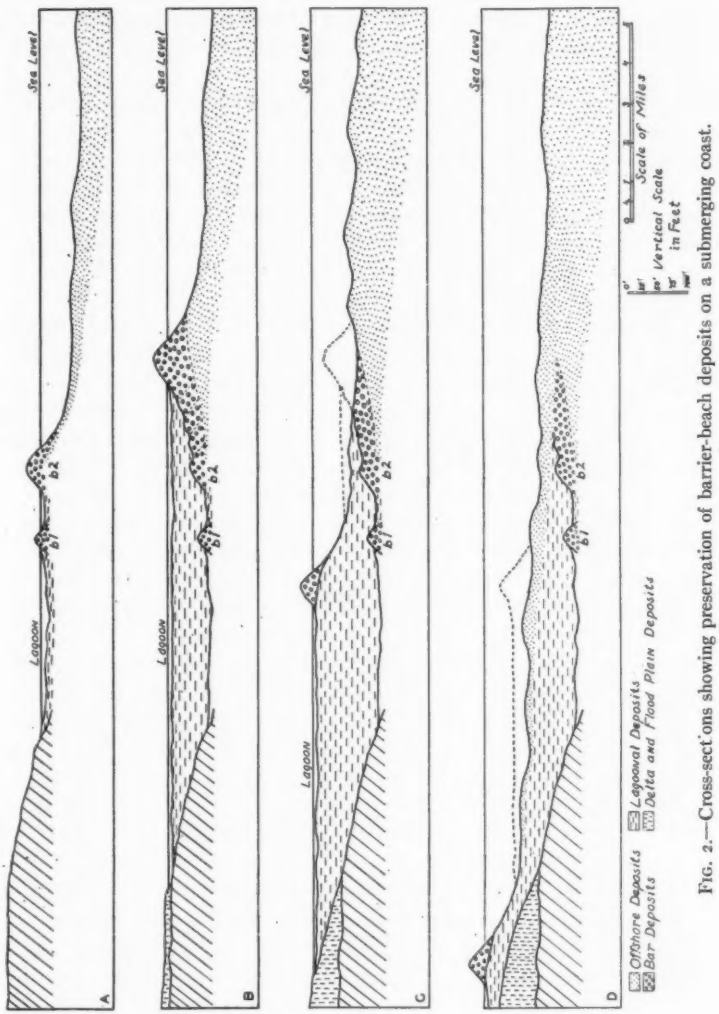

FIG. 2.—Cross-sections showing preservation of barrier-beach deposits on a submerging coast.

are found well developed off portions of the Nile and Mississippi deltas. Where the delta front is holding its own against wave attack on a submerging coast, barrier beaches might be preserved in the manner just described. Likewise if the river carried a very heavy load of detritus, bar and lagoonal deposits would be gradually encroached upon and covered by delta sediments, and ultimately preserved under a cover of these beds.

The two types of bars just described should, theoretically at least, possess certain definite and distinguishing characteristics when preserved in sedimentary strata. Buried submarine bars would probably exhibit a disc-shaped rather than a truly lenticular[1] cross-section. This is due to the fact already mentioned that the deposit would be in part worked over by wave action before preservation. The upper side, however, might show some tendency toward convexity, the lower being practically flat. Due likewise to this re-working, the contact between the sand body and the surrounding strata would probably be gradational, going from a coarse sand into a fine sand or sandy shale. Such a deposit would not be likely to occur within a true shale. The sand body would be elongated in a direction parallel to the ancient shore line. The horizontal dimension at right angles to this would be relatively small, but such sand bodies would not show the extreme narrowness exhibited by barrier beaches or other "shoestring" sands. In general the term "pod-shaped" best describes the outline which buried submarine bars would be most likely to assume on final preservation as lenticular oil reservoirs.

A buried barrier beach should show several very distinctive features. If it was originally of the type of bar *b1*, Figure 2, it would be extremely narrow relative to its length, possibly not more than two or three hundred yards. This does not necessarily follow, however, for if the sand body is the remnant of a once extensive prograded sand- and beach-ridge plain, as is the bar *b2* in Figure 2, *D*, it would be of considerable width, and the entire deposit would exhibit a "pod-shaped" outline. The strike of the sand bodies would be parallel to the ancient shore line, and in any individual case extremely straight. If there is any curvature present it should be very gradual and even, so that the deposit forms a widely swinging arc (*a* in Fig. 3). In the case of a broad deposit of the sand-plain type, this last feature might be exhibited only on the seaward

[1]The term lenticular, although in common use among petroleum geologists and stratigraphers, is nevertheless rather misleading. The vertical dimensions of most so-called lenticular sand bodies are so small compared with the horizontal, that they seldom exhibit in cross-section a true optical lens-like shape, and might be more accurately described as "disc"-shaped.

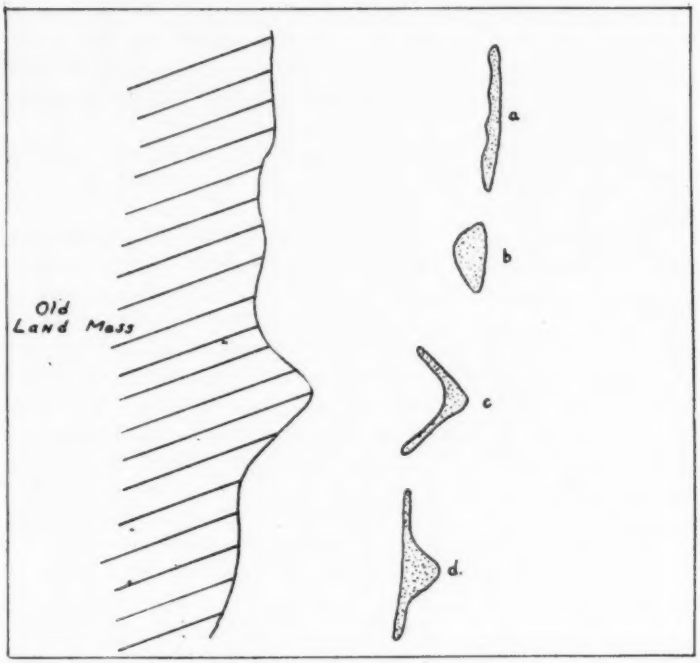

FIG. 3.—Possible shapes of buried barrier-beach sand bodies: *a*, the ordinary, narrow type of offshore bar; *b*, broad sand-plain type; *c*, Cape Hatteras or "elbow" type; *d*, cuspate foreland.

side (*b* in Fig. 3). In any case this side would be straighter and with less irregularities, since it was this side which was exposed to wave attack.

There are a few possible exceptions to this general rule. The buried barrier beach might originally have existed at a point of sudden change in the direction of main shore-line trend. The deposit would then exhibit a decided elbow bend, the point of the elbow being toward the ancient sea (Fig. 3, *c*). There would also be a tendency toward broadening at the bend. Cape Hatteras and Cape Fear are examples of this type of "elbow" bar. It should be noticed, however, that although barrier beaches occur fairly continuously off the Atlantic and Gulf coasts from New Jersey to the Rio Grande, there are very few elbow bars in this entire distance. It is extremely unlikely, therefore, that they would be found preserved in sedimentary strata. A second phenomenon which

might destroy the straight outline of the seaward side of the barrier beach is the building outward of a "cuspate foreland" at some point. This particular type of deposit is taken up in detail on a subsequent page. It would result in an abrupt broadening and thickening of the deposit as shown in Figure 3, *d*.

A buried bar of the type *b1* in Figure 2 would exhibit a cross-section approaching true lenticularity, the composite bar *b2* being more disc-shaped.

The contacts of this type of sand body would differ considerably from those of a submarine bar. The overlying strata are likely to be composed of lagoonal or deltaic sediments and the upper contact would thus be very sharp. The lower contact would be more gradational, the coarse, well-sorted sand of the bar deposit itself grading into the finer and more shaly offshore sands. There might be some interfingering of the lagoonal shales and the sand body due to dune deposits blowing back over the surface of the lagoon or marsh at some time during its history and later being covered up by encroaching lagoonal muds. These associated lagoonal deposits would lie on the former landward side of the sand bar, and might contain coal deposits and terrestrial plant and animal fossils deposited when fresh-water swamp conditions prevailed.

The stratigraphic relations of buried barrier beaches should be favorable for oil accumulation. Lagoonal sediments are generally muds with a high content of organic material; thus, with their intimate ralation to the sand deposit, they would furnish excellent source beds. Offshore submarine bars would not possess such favorable source-bed relationships in this respect. As previously stated, the sediments surrounding them would probably be fine sand or sandy shale, since they occur in a zone characterized by sand deposition.

Porosity is of course very high in a barrier-beach sand body, provided, of course, it has not been reduced by cementation. The sand is highly quartzose, well sorted, and with rounded or perhaps even etched grains from wind action in dunes. The sand of a submarine bar is not so well sorted, particularly if it has been subjected to much re-working. Porosities, therefore, in this type of sand body are not as great as in the other.

The continuity of ancient bar deposits is a very uncertain thing, but should be greatest in a direction parallel to the ancient land mass. As a corollary to this, if one sand reservoir of this type is found in a region, any others at the same stratigraphic horizon will probably have the same strike. Except for possible interfingering of lagoonal shale

bodies, it should be entirely free from breaks. It is possible that some of the extremely narrow shoestring pools of Kansas may represent buried bar deposits. J. L. Rich, in his first paper[1] dealing with this subject, gives two possible examples, namely, the Garnett shoestring and the Colony gas sand, both in Anderson County. Subsequent subsurface information, however, has led to the conclusion that the first named sand body represents an old sand-filled channel, and in the second article,[2] published in June, 1926, he so refers to it. W. K. Cadman has discussed the possibilities of a bar origin for certain shoestring sands in Greenwood County,[3] but has reached the conclusion that they likewise represent sand-filled channels.

Since the shoestring sands of Kansas are found in widely separated areas and at different horizons, and possess varying cross-sections and other characteristics, it is probable that they have been formed by several different sedimentary processes, and the proof of the origin of the sands in one district can not necessarily be applied to another.

Theoretically an examination of the lithologic characteristics of these questionable deposits should yield some useful data that would be of aid in distinguishing bar and channel sands. The sands of the former should be well sorted, well rounded, and highly quartzose. Of course a channel sand might exhibit these same properties, particularly where rivers drained a sandstone country. It is extremely unlikely, however, that a bar deposit would be composed of poorly-sorted, angular and sub-angular grains, with plentiful mica, feldspar, and other minerals, as is ordinarily the case with channel sands.

Proven examples of buried sand-bar deposits can not be cited without more detailed subsurface information.

HOOKS, SPITS AND BARS BUILT OUT INTO DEEP WATER

Many lenticular reservoirs undoubtedly originated as sand spits, hooks, and cuspate forelands, built out from a main shore into deep water, where, the bottom being well below the profile of equilibrium, they were safe from destruction and were ultimately buried under a

[1] J. L. Rich, "Shoestring Sands of Eastern Kansas," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 7, No. 2 (March-April, 1923).

[2] *Idem.*, "Further Observations on Shoestring Oil Pools of Eastern Kansas," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 10, No. 6 (June, 1926).

[3] W. K. Cadman, "The Golden Lanes of Greenwood County, Kansas," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 11, No. 11 (November, 1927).

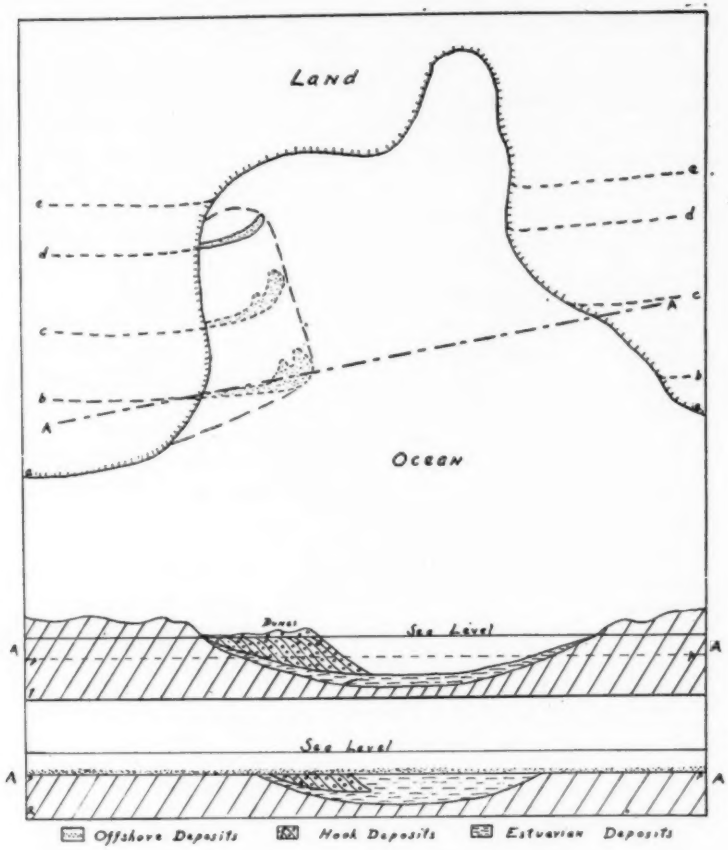

FIG. 4.—Sketch showing the history of a hook deposit built into deep water on a retrograding shore. *a-a*, *b-b*, *c-c*, etc., represent successive positions of the shore line. Cross-section No. 1 shows conditions when the shore line is at stage *b-b;* cross-section No. 2 is along the same line at stage *e-e* of shore-line development; *p-p* in each case is the profile of equilibrium.

protective cover of sediment.[1] Figure 4 illustrates the basic principles here involved. As wave erosion cuts the coast back from its original position *a-a*, longshore currents and beach drifting gradually build up a

[1]This process has been discussed by Roswell H. Johnson in his paper "The Time Factor in the Accumulation of Oil and Gas," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 5, No. 4 (July-August, 1921).

sand spit across the mouth of the bay from material which they deposit on entering the deep water at the bay mouth. Wind and tidal actions tend to turn the end of the spit into a hooked form as shown in the sketch, where *b-b*, *c-c*, *d-d*, *e-e*, represent successive stages of shore-line development as wave attack pushes the shore farther and farther inland. Sandy Hook, New Jersey, at the entrance to New York Bay, is an example of a formation of this type, and is probably in the stage of development shown at *b-b*.

The two cross-sections along the line *A-A* illustrate the mode of preservation of sand-spit material. The first shows the conditions at stage *b*, with the hook built well above sea-level, particularly at the outer end where dune conditions are most likely to prevail. With the eroding back of the shore line, all the material above the profile of equilibrium, *p-p*, is destroyed and washed away. If we assume a sinking shore, however (and this is likely to be the case, for sand spits and hooks are typical of submerging rather than emerging coast lines), the remains of the original sand hook are buried under a cover of offshore sediments, and the final result is a lenticular sand body overlain and underlain by offshore and estuarine deposits, respectively. Notice that this final deposit will probably have such an outline as indicated by the dashed line in Figure 4. This is the result of the total deposition as the bar moves back from its original position. Thus the long axis of the sand body is at right angles to the shore line, and in any case the final body as it is preserved in the strata will be a composite affair, and will not necessarily exhibit a hook or spit outline.

There are two other types of shore-line phenomena which may be built up in deep water so that a part, at least, of the sand body is below the profile of equilibrium. The first of these is a cuspate foreland. This may be described best as a triangular point of sand built outward from the mainland by prograding in a series of dunes and swales. Cape Carnaveral on the east coast of Florida is the classic example of a cuspate foreland. There are several different types recognized, any one of which may owe its origin to one factor, or a combination of them, such as a change in outline of the main shore or the configuration of the sea bottom, or possibly a shift in the longshore currents. D. W. Johnson discusses these questions in considerable detail in his book, *Shore-line Processes and Shore-line Development*, pages 319 to 325.

Wherever prograding has been sufficient, the seaward end of the sand body is built out into water deep enough to carry it below the profile of equilibrium in the event of subsequent submergence of the coast

and destruction of the foreland. Thus this outer part would be preserved under a cover of offshore sediments.

The outline of the preserved sand body would not necessarily have the triangular shape of the original foreland. The entire deposit may migrate along the coast, due to erosion on one side of the point and deposition on the other. Under such conditions a lenticular pod-shaped sand body parallel to the coast would be the final result. If only the outer part, which was built in the deepest water, is preserved, then the outline would be quite irregular.

The second type of shore-line phenomena, which may be built out into comparatively deep water, is a tombolo or tie-bar, that is, a bar uniting an island with the mainland or an island with another island. Examples of tombolos are common along the New England coast south of Maine (Fig. 5).

They originate from several complex causes, chief among which are wave and current action. Where the depth of water between island and mainland is greater than the depth of the profile of equilibrium, the lower part of a tombolo would be preserved within finer sediments, even after the island itself had been planed off. Islands are characteristic of submerging coast lines, a condition which in itself increases their chances of preservation.

A buried tombolo might be preserved in very nearly its original outline, particularly when deep water existed close to the island and mainland. Migration of the deposit is not likely, although a change in the direction of prevailing winds or currents might bring this about.

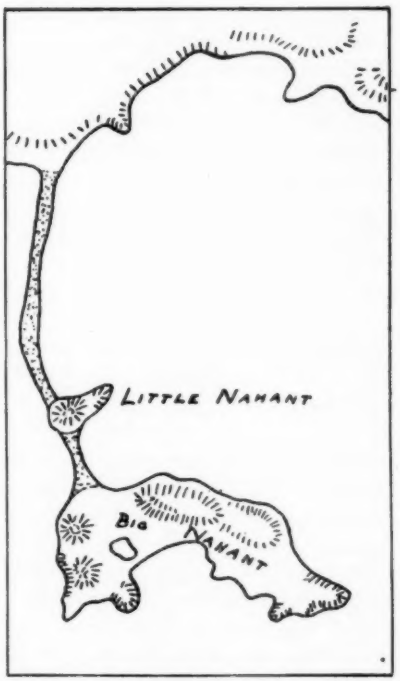

FIG. 5.—A typical tombolo uniting two islands with the mainland. (After D. W. Johnson.)

Double and complex tombolos are known, but in general an oil reservoir formed in this way would probably be long and narrow, or at least pod-shaped. Notice, however, that in contrast to buried bars and buried barrier beaches the strike of tombolos would bear little or no relation to the ancient shore line.

In summing up the characteristics exhibited by buried spits, hooks, tombolos, and forelands, there is little to add, except to bring out more fully the resemblances and differences of the various types. The degree of lenticularity would probably be highest in buried tombolos, provided, of course, that the cross-section is at right angles to the strike. In other types there would be wide variation, but in most cases the cross-section would be disc-shaped. It does not seem likely that these sand bodies would exhibit any great degree of convexity on either upper or lower surface. As shown in Figure 4, the lower side of current-built spits and hooks would have a slight tendency toward convexity, while the upper side, having been planed by the sea, would be relatively flat. This would be true to a less degree in a tombolo, and all types would probably have lens-like terminations through a series of interfingerings.

The type of sand body shown in Figure 4 is underlain by estuarine sediments and overlain by offshore sediments. This is due to the fact that the hook is built out into the entrance of the bay, and the sand composing it is deposited on top of the sediments of that facies. After the sea has transgressed inland and scoured out all material above the profile of equilibrium, deposition of offshore sediments commences again. It does not necessarily follow that the sediments of these two zones will differ from each other in character, but theoretically, at least, one would expect to find the finer muds and shales of an estuarine environment below the sand body and the coarser offshore sands and sandy shales above. This difference would not be so likely to occur in a cuspate foreland, particularly where it had originally been built out into an open sea, as is the case of Cape Carnaveral. Some cuspate forelands are built at the entrance to bays, and here there might be a difference in overlying and underlying beds. This condition might or might not be found in a buried tombolo, depending on the original location of the sand deposit. If the latter had once inclosed a bay of considerable size, it is probable that the sediments deposited on the bay side would differ considerably from those on the ocean side. In all cases it seems likely that the lower contact would be sharper than the upper, since re-working would tend to make the latter gradational.

The shapes of the sand bodies after final preservation in sedimentary strata would probably be exceedingly irregular with the single exception of the tombolo. The latter, as has been pointed out, might in this respect closely resemble a buried barrier beach, but with these important differences: its strike would, more likely than otherwise, be at right angles to the ancient shore line, while that of a buried barrier beach would be parallel; a tombolo deposit would not be likely to show the extreme straightness of a barrier beach; lastly a buried barrier beach would be more likely to show a truly convex upper surface.

Buried hooks, spits, and cuspate forelands might exhibit any shape of outline, circular, pod-shaped, elongate, or highly irregular, but unlike the barrier-beach or offshore-bar reservoir there would be no correlation between the strike of an elongate body of this origin and the ancient shore line. Those forms built out into an embayment of the sea are surrounded in part by sediments of estuarine origin. The latter are likely to be fine-grained with a high organic content, and well suited to serve as source beds. Even buried cuspate forelands and tombolos, built out perhaps originally into an open sea, may be surrounded by fine sediments possessing the necessary source-bed properties.

Porosities of such reservoir rocks should be high, since bars, spits, and hooks are generally composed of coarse, well-sorted quartz sand. Local breaks of finer sand or shale are likely to be encountered, representing periods in the bar's history when it was partly or wholly destroyed by the sea and later built up again. Shale interfingerings should also be common along the boundaries of the reservoir. Compound recurved spits and similar forms are exceedingly complex, with minor bars and spits attached to the main body. Periods of such complexity would probably be represented in the final deposit by breaks and irregularities in thickness. Such sandstone reservoirs are not necessarily of small areal extent, however. The wave- and current-built hook at the tip of Cape Cod in Massachusetts Bay has an area above water of 8 or 9 square miles.

"Stray" sands and sands producing in only a very small portion of a pool are of common occurrence in the Mid-Continent oil fields, and in the opinion of the writer many of them may be accounted for as original minor shore-line sand bodies. Where production seems to come from a lenticular coarse portion of a larger and more sheet-like body, this productive portion may represent an ancient hook or spit deposit built in a facies of sand deposition; hence, entirely surrounded by a finer sand. Excellent examples of sand bodies of this type are the productive "pays"

of the Hundred-foot sand in the Sewickley quadrangle, Pennsylvania. There the oil and gas seem to be confined to coarse conglomeratic lenses within the main sheet sand. The lenses are elongate and in general strike north of east, which was the probable trend of the ancient shore line. Thus it seems likely that many of the producing oil reservoirs of the Appalachian fields originated as offshore bars, barrier beaches, and hooks, and now occur as coarse lenticular sand bodies in sheet-like finer sandstones and sandy shales.

Figure 6 shows the outline of some of the elongate pools of the Sewickley quadrangle.[1] Notice that the trend is prevailingly northeast-southwest with a few outstanding exceptions. One of these is the small pool on the Beaver-Allegheny county line which strikes northwest toward a larger pool, which itself trends slightly west of north. The small pool and the southeast prong of the main pool might be interpreted as buried tombolo sand bodies, connecting an ancient shore line with a large system of bar or hook deposits. About 3 miles southwest is another pool striking northwest. The largest pool of the area has the normal direction of strike and may represent a composite bar and hook deposit.

Another interpretation which might be put on the group of pools with the northwest strike in Beaver County is that they represent channel deposits,—either delta distributaries diverging toward the southeast, streams converging toward the northwest, or possibly a system of tidal channels. A delta distributary origin is not likely, since the hypothetical channels diverge southeastward, and the sea basin of the period lay presumably in the other direction. Neither are the surrounding sediments of the Hundred-foot sand of delta material. The convergence of the reservoirs toward the northwest is what one would expect in the stream-drainage pattern at the time of deposition. The coarse lenticular lenses, however, are conformably interbedded in the marine Hundred-foot sand which precludes this origin. Tidal channels in lagoons and estuaries ordinarily have associated lagoonal and estuarine muds which are lacking here. It seems more likely, therefore, that these deposits originated as shore-line phenomena.

CONCLUSION

In a paper of this length it is not possible to deal adequately with all the many complex types of lenticular reservoirs, nor describe all the processes which might lead to their preservation. From this brief dis-

[1] M. J. Munn, *U. S. Geol. Survey, Sewickley Folio.*

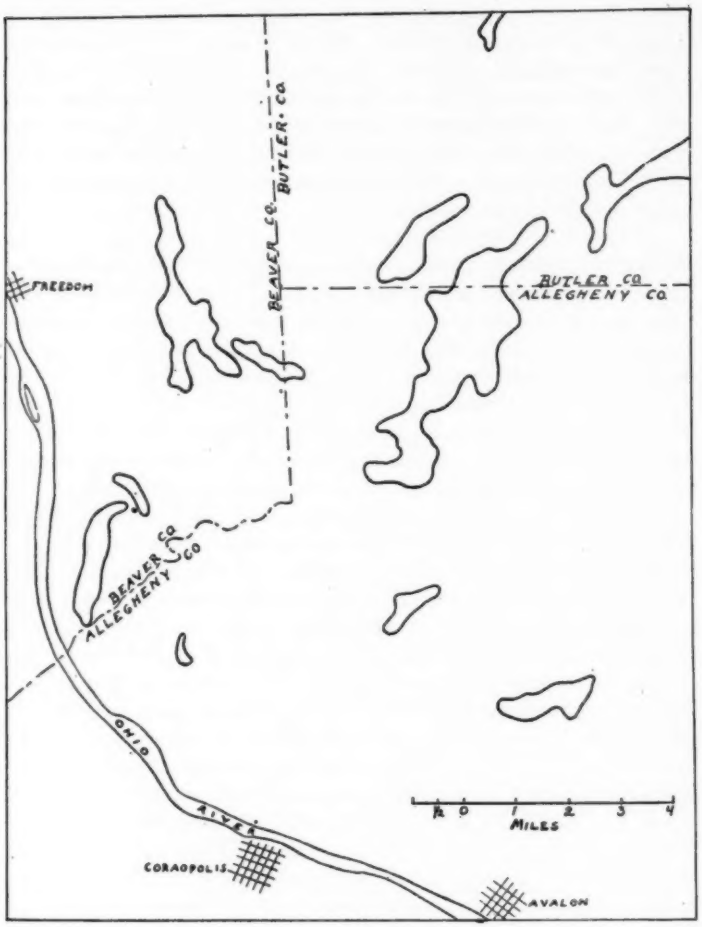

FIG. 6.—Oil-pool map of the Sewickley quadrangle, Pennsylvania. Pools shown in outline. (After M. J. Munn.)

cussion, however, it may be seen that a knowledge of the origin of lenticular oil sands may be of great value in determining the thickness, strike, limits, and potential productivity of such sands.

Of course subsurface evidence is at best scanty and unreliable, and much of it is conflicting if used as support for a particular theory of origin. However, the knowledge of the processes of deposition and preservation of the various types of shore-line sand bodies serves as a starting point; and although one may not be able accurately to classify a doubtful oil sand, at least one can eliminate some theories of origin, and in doing so perhaps save much unnecessary dry-hole drilling.

EXPERIMENTS RELATING TO FACTORS CAUSING LOCALIZATION OF FOLDS[1]

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ABSTRACT

The results of certain experiments indicate that several factors are capable of localizing folds, that domes are more readily formed than basins, and that folds formed by several successive periods of compression tend to persist vertically. Factors other than settling may explain the localization of folds over buried hills.

The effect of previously formed folds, points of weakness, ridges, and points of flexure upon the localization of folds was studied experimentally in order to help solve problems arising from a study of the folds of Osage County, Oklahoma.

EFFECT OF WEAKNESS IN BEDS

An elongate block (76 cm long, 5 cm. wide, and 4 cm. thick) composed of five alternating layers of pure vaseline and a more resistant (paraffin-vaseline) mixture, placed one above another, and having cross-sections of unequal strength, was compressed in the direction of the block. As might have been expected, deformation occurred where the block was weakest, that is, where the more resistant material was thinnest. The deformation consisted of faulting in the lower layers and folding in the upper layers.

EFFECT OF RIDGES

In Osage County, the surface of the igneous rocks underlying the sedimentary formations is irregular. What effect do these irregularities have upon the localization of folds? Three conditions were simulated in the laboratory, the application of compression to (1) the granite, (2) the sedimentary beds overlying the granite, and (3) both the granite and the sedimentary beds.

[1]A part of a doctor's thesis, University of Chicago, 1927. Manuscript received by the editor, January 4, 1928.

[2]Geologist, 752 South Olympia.

Compression of the underlying granite.—The granite was represented by elongate blocks (40 cm. long, 5 cm. high, and 3 cm. wide) having transverse ridges (1.5 cm. high and 3 cm. wide) which were composed of a homogeneous mixture of paraffin (1 part) and vaseline (2 or 3 parts). Compression was applied in the direction of the long dimension of the block and at right angles to the ridge. In three out of the four cases, deformation occurred at the ridge, twice resulting in folding and once in faulting—the localization of the deformation at the ridge probably being due to the irregular stresses developed at this point.

Compression of sedimentary beds.—The underlying granitic rocks with their peaks and ridges were represented by long wooden blocks to which were attached smaller wooden blocks in the form of transverse ridges. These ridged surfaces formed the bottom of molds into which was poured a mixture of paraffin (1 part) and vaseline (2 parts). The sides of the mold were then removed and compression, in a horizontal plane and perpendicular to the ridges, was applied to the paraffin-vaseline blocks. Folds or faults formed above the ridges; the localization of the deformation at such points in all of these experiments may be attributed to the thinness of the paraffin-vaseline block at this point and the consequent local weakness.

Compression of both granite and overlying sediments.—The granite and its uneven surface was represented by oblong blocks composed of a homogeneous mixture of paraffin (1 part) and vaseline (2 parts) having transverse ridges of the same material. Over each ridged block and simulating the sedimentary beds, were molded four or six alternating layers of pure vaseline and the paraffin-vaseline mixture. The ridge rose above the two lower layers dividing them into two parts, one on each side of the ridge; the other layers were continuous, extending over the top of the ridge. Horizontal compressive forces were applied perpendicular to the ridge. Several factors influenced the resulting deformation. In one case, a fold was formed at the ridge in the underlying portion of the block while a fault developed on one side, both apparently being due to the unequal stresses developed at this point. The fold in the lower part of the block was reflected upward, forming the major fold in the overlying beds. The sliding of the more resistant beds along the ridge formed minor folds in the upper beds on the sides of the major fold (Fig. 1). In the second block, the upper beds folded above the ridge, the deformation probably being due to the weakness of the beds at this point; the lower portion of the block was not deformed.

FIG. 1.—Figure illustrating the various ways in which the effects of compression were localized by a buried ridge. The light-colored material is composed of vaseline (2 parts) and paraffin (1 part); it represents the more resistant rocks. The lowest layer represents granite having a mountainous topography; the upper layers represent sandstones or limestones. The dark-colored material is pure vaseline and represents shale. When the above block was compressed, folding and faulting developed at the ridge in the lowest layer and, in turn, formed the major fold in the overlying layers. Sliding of the more resistant beds over the arch developed minor folds on either side of the major folds. The block is about 32 cm. long.

Geological significance.—The foregoing experiments suggest that compression may localize folds over buried granitic hills, due to the local weakness of the overlying beds or to the movement of the more competent beds over the buried granite hills. Possibly, irregular stresses developed within the granite may also result in folding. While many of the known buried hills are composed of granite, hills composed of other types of rock may act in a similar manner.

The anticline of the Crinerville oil field, Carter County, Oklahoma, is located above a buried hill, which probably was the determining factor in the localization of the fold. However, it is considered that tangential compression rather than compacting of the overlying sediments was the active force which formed the anticline.[1]

EFFECT OF POINTS OF FLEXURE IN LOCALIZING FOLDS

Are irregularities in the sedimentary beds, either in the form of gentle arches or shallow troughs, capable of localizing later folding? In an endeavor to answer this question twenty-five or more experiments were performed. Several layers of various mixtures of paraffin and vaseline were molded one on top of another to form elongate blocks (2 to 4 cm. high, 5 cm. wide, and 25 to 76 cm. long); in each block one or more layers were molded in the form of an arch or a trough, located at various distances from the end of the blocks. Compression was applied to the blocks in the direction of their long axes. In most of the experiments with arches, folds formed directly over the arches, but in none of the experiments with troughs were folds formed over the troughs. This

[1] Sidney Powers, "Crinerville Oil Field, Carter County, Oklahoma," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 11, No. 10 (October, 1927), pp. 1067-85.

is all the more remarkable as in some instances the same blocks were used to represent both troughs and arches, the blocks containing the troughs being inverted to form the arches. The failure to develop folds over a trough may be attributed to the inability of the beds to bend downward, being opposed by the presence of the wooden blocks. In the earth's crust upward bending is opposed by the force of gravity, but the resistance to downward bending is much greater, being opposed by the presence of other strata which must either be compressed or pushed aside. The greater number and size of the domes of Osage County as compared with the basins may be explained on this basis. The localization of the folds above arches illustrates how irregularities in the sedimentary beds, either original or secondary, may localize folds.

FOLDING BY SUCCESSIVE COMPRESSIVE FORCES

The principle underlying the following four experiments is the same as that of the preceding experiments, but instead of applying compressive forces only once, they were applied several times, and between the applications of pressure additional layers were molded to the paraffin-vaseline blocks. In the first experiment a bed of uniform thickness consisting of vaseline (2 parts) and paraffin (1 part) was folded so that a portion of it formed an arch .4 cm. high with a span of 6 cm. Melted vaseline was then poured over this block until the arch was covered and an even surface formed, over which was poured a mixture of paraffin (1 part) and vaseline (2 parts). The block was then inverted and similar layers were added to the bottom, making a total of five layers (Fig. 2). Under compression, the block folded, the folding being localized by the arch in the middle layer (Fig. 3). Upon the addition of new layers at both top and bottom (Fig. 4), and after further compression and consequent folding, the new folds were again localized at the arch (Fig. 5). The second experiment was performed in an identical manner and with similar results.

Conditions of overlap and erosional unconformity were simulated in the third and fourth experiments, respectively. In these experiments two blocks were used; each of them consisted of five layers, with an arch in the middle layer, and was similar to those used in the preceding experiments (Fig. 2). These blocks were then compressed, causing them to fold. Four layers, two vaseline-paraffin layers alternating with two pure vaseline layers, were then molded on top of each block. In the third experiment, the lower two of the additional layers were interrupted by the arch against which they abutted, while in the fourth experiment,

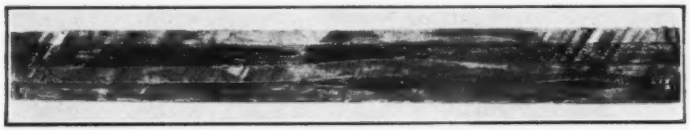

FIG. 2.—Initial block of five layers used in first experiment on folding by successive compressive forces.

FIG. 3.—Model shown in Figure 2 after compression was applied.

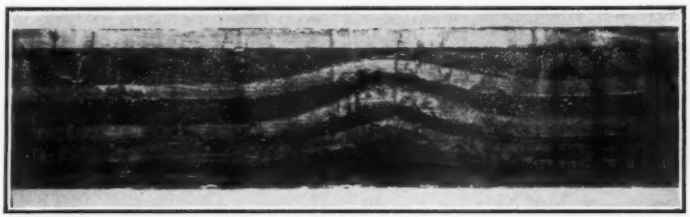

FIG. 4.—Model shown in Figure 3 after layers were added to top and bottom.

FIG. 5.—Model shown in Figure 4 after compression was applied.

FIGS. 2, 3, 4, and 5.—These figures show the successive deformation of a block illustrating how folds will persist vertically through great thicknesses of sediments and how folds developed at any given time will tend to localize all future folding. The dark layers are composed of pure vaseline and represent the less resistant strata; the lighter-colored ones are composed of a mixture of vaseline (2 parts) and paraffin (1 part) and represent the more resistant beds. The blocks are approximately 32 cm. long.

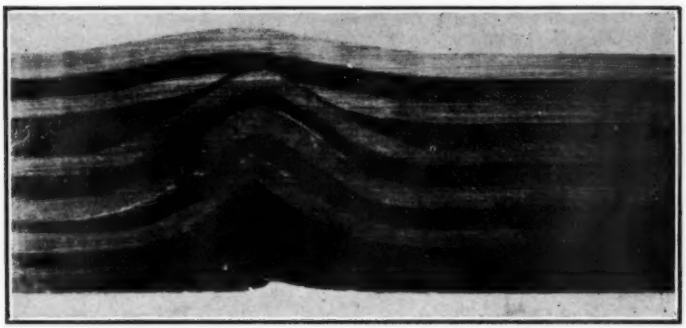

FIG. 6

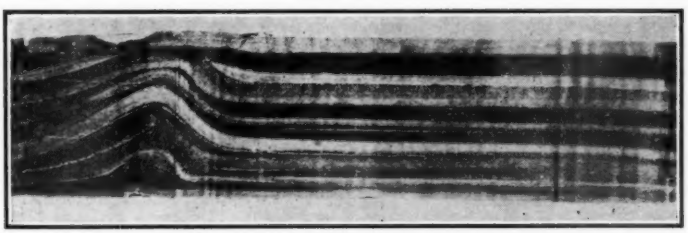

FIG. 7

FIGS. 6 and 7.—Figures illustrating the conditions of overlap and erosional unconformity and showing how folds persist vertically through unconformities. The blocks were formed by alternately applying compression and adding new layers in a manner similar to that of experiments 1 and 2. (See Figures 2-5, inclusive.) The dark layers are composed of pure vaseline and represent weak beds such as shale; the lighter-colored layers are composed of a mixture of vaseline (2 parts) and paraffin (1 part) and represent the more resistant beds such as limestones or massive sandstones. The folding has all been localized by a slight arch in one of the beds of the original block, and as folds developed they, in turn, assisted in the localization of later folding. In Figure 7, careful observation is required to detect the fold of the top surface developed by the last application of compression.

all four layers extended across the top of the arch. The blocks were then inverted and one layer of pure vaseline and one of the vaseline-paraffin mixture were added. The blocks (in an upright position) were then compressed, folds again being produced. In the fourth experiment, the top layer was truncated from the top of the fold; new layers were added to the top and bottom and the block again compressed, with further folding. In both experiments, as in the preceding ones, folding was

localized by the original arch and by the folds which subsequently formed at the same place (Figs. 6 and 7).

These experiments all illustrate how folds formed by successive compression may persist vertically through unconformities or through great thicknesses of sedimentary formations.

CONCLUSIONS

1. Folds formed by compression may be localized by several factors, such as weakness in beds, points of flexure, previously formed folds, and underlying buried hills.

2. Folds formed by compression may be localized over buried granite hills either (1) through the peculiarities in the response of the rocks to the compression itself, or (2) by the influence of dips sloping away on all sides from buried hills, the dips having been formed by the settling of sedimentary beds over the hills.

3. Compressive forces form domes more readily than basins; therefore domes produced by such forces should be larger and more numerous than basins so formed.

4. Folds formed by successive periods of compression tend to persist vertically through unconformities or through great thicknesses of sedimentary formations.

DEVELOPMENT IN SOUTHERN CALIFORNIA SINCE 1923[1]

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ABSTRACT

The writers discuss recent developments in the Los Angeles basin, calling attention to the following fields: Dominguez, Rosecrans, Inglewood, Los Cerritos, Huntington Beach townsite, Seal Beach and Potrero districts, and the deep production at Long Beach. They point out the importance of faulting in confusing structures. Oil is being produced from the Miocene in districts where the Pliocene was formerly thought to be the only source.

Developments in the Los Angeles basin during the past four and a half years have been of great importance to the oil industry of California and to the entire United States. Discoveries have been made with such frequency and regularity that it is fair to assume that future developments will result in further discoveries. It must, nevertheless, be admitted that the expectancy of new fields of major importance is much less certain than it has been at any time in the past five years. However, additional oil may be expected from deeper sands known to exist in several fields in the basin. It is also fair to assume that deeper and uncharted oil zones will be found in others that have not yet been tested.

The intensive development of Santa Fé Springs, Long Beach, and Huntington Beach fields brought California prominently before the oil world in 1923. There have been discoveries in the intervening period of equal importance to the geologist, which emphasized the soundness of the original geological recommendations advanced for development work. They have also served to bring out the fact that ours is a progressive science and that new things are constantly being learned in drilling wells and in the development of oil fields.

Prior to 1923 the district in the vicinity of Los Angeles, extending to the ocean, was referred to as the Los Angeles coastal plain. By 1923 it was generally recognized that this district should more properly be

[1]Read before the Association at the San Francisco meeting, March 23, 1928. Published with the permission of J. A. Taff, chief geologist, Associated Oil Company, San Francisco, California.

[2]476 Associated Oil Building, San Francisco.

[3]766 Pacific Electric Building, Los Angeles.

referred to as the Los Angeles basin. The mountains hemming it in on the northeast side and the northwest and southeast ends are so prominent that no question as to them could be raised. The southwest rim of the basin was represented only by the Palos Verdes Hills and the possibility that certain islands in the ocean might represent the remnant of that rim.

By 1923 all of the oil fields on the northeast side of the basin had been found and were in the process of development. The principal developments since 1923 have been confined to the fields on the southwest side of the basin. These are located in a straight line of hills, extending from Palms to Newport. This general uplift is sometimes referred to as the Palms-to-Newport uplift.

Interesting facts relative to fields in the basin that had reached their peak of production prior to the end of 1923, are tabulated in Table I. These fields have been listed in their geographic position from west to east (Fig. 1).

Table II has been compiled for the purpose of showing the same information relative to the fields that have reached their peak of production since 1923. These have been arranged in chronological order according to the time they reached their peak of production.

Figure 1 shows the Los Angeles basin oil fields as of January, 1928.

As previously stated, all of the discoveries since 1923 in the Los Angeles basin have been confined to the Palms-to-Newport uplift.

Figure 2 shows the oil fields along the Palms-to-Newport uplift at the present time. The areas developed prior to July, 1923, are shown in solid black, while the areas developed since 1923 are cross-hatched.

Figure 2, in addition to showing the oil fields, also shows the approximate limits of the topography in this Palms-to-Newport uplift. Despite the prominence of this topography, the oil fields contained beneath the various important features were not found as readily as one might expect, nor were they discovered as a result of the first prospecting in each district. On the contrary, every oil field found since 1923 has been found only after several dry holes were drilled and sufficient data accumulated to indicate the proper point for the discovery well. This feature stands out so prominently in the history of every field that it should serve as a most important element of encouragement to the geologist who feels that he is fundamentally right in his interpretation. He may well adhere to his views even in the face of apparently discouraging results of the first wells drilled.

TABLE I

DATA RELATIVE TO OIL FIELDS OF LOS ANGELES BASIN THAT REACHED THEIR PEAK OF PRODUCTION PRIOR TO THE END OF 1923

Field	DISCOVERY				Maximum Daily Production		No. of Wells	Present Daily Production	No. of Wells	Approximate Depth in Feet	Deg. Be. Gravity	Total Barrels Produced to Jan. 1, 1928	Approximate Proven Acreage
	Company	Well	Date	Depth in Feet	Date	Barrels							
Salt Lake—Beverly Hills and Los Angeles	Several	.....	.....	1,893	1909	14,000	643	2,050	384	250-4,200	10-23	61,481,562	2,325
Montebello	Standard Oil	Baldwin No. 1	2/27/17	2,395	6/1919	41,653	....	13,000	161	1,500-4,400	19-30	75,812,146	1,175
Whittier	Central Oil Co.	.....	.....	1,886	6/19/17	5,500	....	1,755	178	700-3,360	14-23	12,907,491	903
Santa Fé Springs	Union Oil Co.	Meyer No. 3	10/3/19	4,595	8/1923	341,500	188	37,800	316	3,500-5,100	24-36	169,148,029	1,600
Coyote	Standard Oil Co.	Murphy Coyote No. 1	1/15/26	3,490	6/1918	31,600	....	13,500	194	2,600-4,600	14-30	111,330,171	980
Olinda and Fullerton	.....	.....	1897	....	7–1914	18,000	....	12,500	419	500-4,700	16-25	123,150,961	3,150
Richfield	Union Oil Co.	Chapman No. 1	3/11/19	3,060	10/2/21	30,673	109	20,000	245	2,100-4,700	15-25	48,334,389	1,275
Long Beach	Shell Co.	Alamitos No. 1	6/20/21	3,114	10/1923	283,751	299	123,900	631	2,300-5,900	21-31	260,156,415	1,300
Huntington Beach	Standard Oil Co.	Huntington No. A-1	8/3/20	2,381	4/1923	116,000	168	58,200	556	2,000-5,000	17-28	126,901,332	2,350

TABLE II

DATA RELATIVE TO OIL FIELDS OF LOS ANGELES BASIN THAT REACHED THEIR PEAK OF PRODUCTION SUBSEQUENT TO THE END OF 1923

Field	DISCOVERY				Maximum Daily Production		No. of Wells	Present Daily Production	No. of Wells	Approximate Depth in Feet	Deg. Bé. Gravity	Total Barrels Produced to Jan. 1, 1928	Approximate Proven Acreage
	Company	Well	Date	Depth in Feet	Date	Barrels							
Torrance	C. C. M. O. Co.	Del Amo No. 1	6/6/22	3,500	5/1924	75,978	378	19,500	647	2,790-4,100	11-28	52,829,439	4,500
Dominguez	Union Oil Co.	Callender No. 1-A	9/1/23	4,068	1/1925	62,861	42	12,500	72	3,900-4,900	26-35	34,110,141	645
Inglewood	Standard Oil Co.	L. A. Invest. No. 1-1	10/10/24	2,134	7/29/25	115,385	120	30,000	214	1,225-2,800	14-29	49,181,833	750
Athens-Rosecrans	Union Oil Co.	Rosecrans No. 1	3/25/24	3,926	.....	.....	....	.....	....	.....	....	.....	...
Athens-Rosecrans	Union Oil Co.	Howard Park No. 1	5/5/24	4,971	10/15/25	31,095	92	7,000	110	4,190-7,591	26-43	17,635,848	370
Huntington Beach Townsite	Standard	B-2	12/27/21	4,245	12/27/26	61,906	83	24,164	217	3,300-4,300	16-26	.....	320
Seal Beach	Marland Oil Co.	Bixby No. 2	8/4/26	4,427	6/13/27	78,358	74	41,500	128	4,340-6,608	23-28.5	17,015,137	348

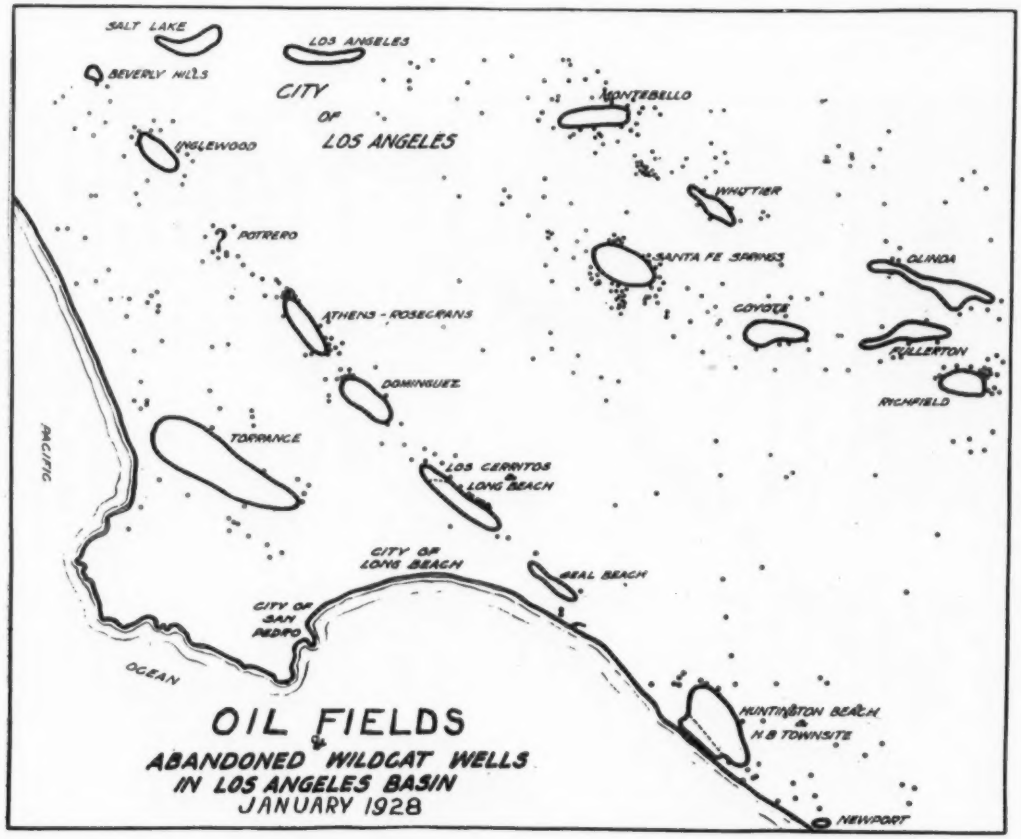

FIG. 1.—Map of oil fields and abandoned wildcat wells in Los Angeles basin. Distance from Beverly Hills southeast to Newport field is approximately 43 miles.

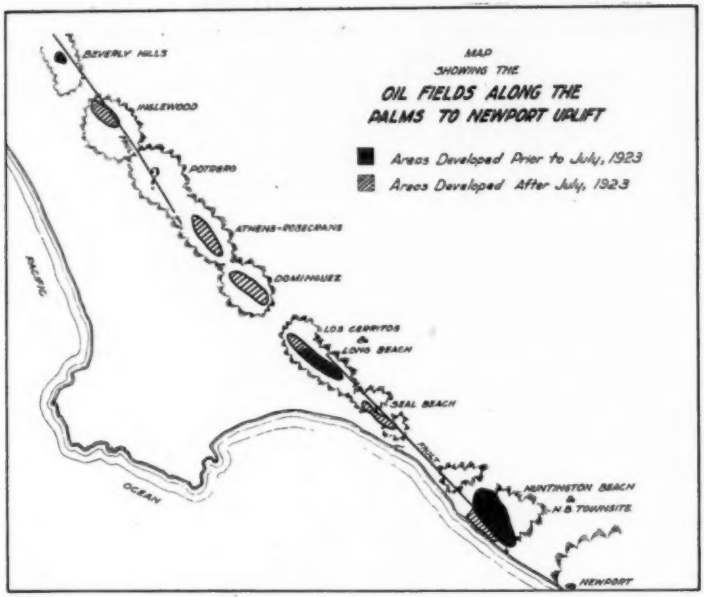

FIG. 2.—Map showing the oil fields along the Palms-to-Newport uplift. Distance from Beverly Hills is approximately 43 miles.

In the development of each oil field in the past five years some new feature has been brought out in a particularly prominent way.

The Torrance oil field lies in front of the Palos Verdes Hills, in an area fairly well covered with sand dunes, devoid of any prominent suggestive topography. This field had been found in 1922, but its development as a producer of heavy oil at a depth of 3,000 feet had not proved embarrassing that year nor during the following year. Just as it was well recognized that the peak of production had been passed in 1923, another discovery opened an extremely large area for further drilling. The new town-lot campaign developed rapidly. With the performance of Santa Fé Springs and Long Beach clearly in mind, there was room for fear that this situation might go beyond control. As the oil-producing zone proved to be only a few hundred feet thick, no great over-production developed. Deep tests demonstrated that the production came from the Pliocene formation, and that the Miocene formation lying immediately below it did not contain commercial production.

In the year 1924 the same sort of deep test in the Beverly Hills oil field also demonstrated that the Miocene immediately below the Pliocene did not contain oil in paying quantities.

The next oil field to come into prominence was the Dominguez field. Figure 3 shows the topography of this field and brings out the fact that the oil-producing area is located exactly where geologists thought it should be, despite the doubt created, by early drilling, as to the soundness of this view.

The Highland Petroleum Company well was drilled to a depth of 3,661 feet. It found some oil and gas, but lack of money prevented deeper drilling. The Standard Oil Company drilled its Dominguez No. 2 to a depth of 5,005 feet. This test was accepted in 1917 by some as proving that there was no oil in these hills. As a result, the General Petroleum abandoned its Carson No. 1 well at a depth of 1,622 feet. The area lay inactive until 1923 when the Union Oil Company drilled its discovery well, Callender No. 1, just a few hundred feet northeast of the General Petroleum's Carson well.

The Dominguez field is of particular interest in that all wells drilled in it were spaced 610 feet apart, or one well to 8.54 acres. Figure 4 shows the subsurface structure and the wide regular spacing of the wells. Development of the oil zone was limited to 400 feet of formation below the water shut-off, where that much penetration was possible. On the top of the structure the same 400 feet of zone has not been developed that is developed on the plunge. There is probably as much as 500 to 600 feet of zone which has been subject to this uniform development campaign.

Additional deeper oil was found in 1927 in the northwest end of the field. This deeper zone may not be as extensive as the upper zone, but it promises to furnish a large volume of light-gravity oil when conditions in the industry justify its development.

The gas lift has probably been used more successfully in this field than in any other in California. To-day there are nearly as many wells producing by means of the gas lift as there are flowing and pumping wells combined, and the total production from the wells on the gas lift is greater than the combined production of the pumping and flowing wells.

PRODUCTION BY PUMPING, FLOWING, AND GAS-LIFT

22 wells pumping 2,269 barrels, average per well.....103 bbls.
17 wells flowing 4,515 barrels, average per well.....265 bbls.
33 wells on compressor, 6,859 barrels, average per well.....207 bbls.

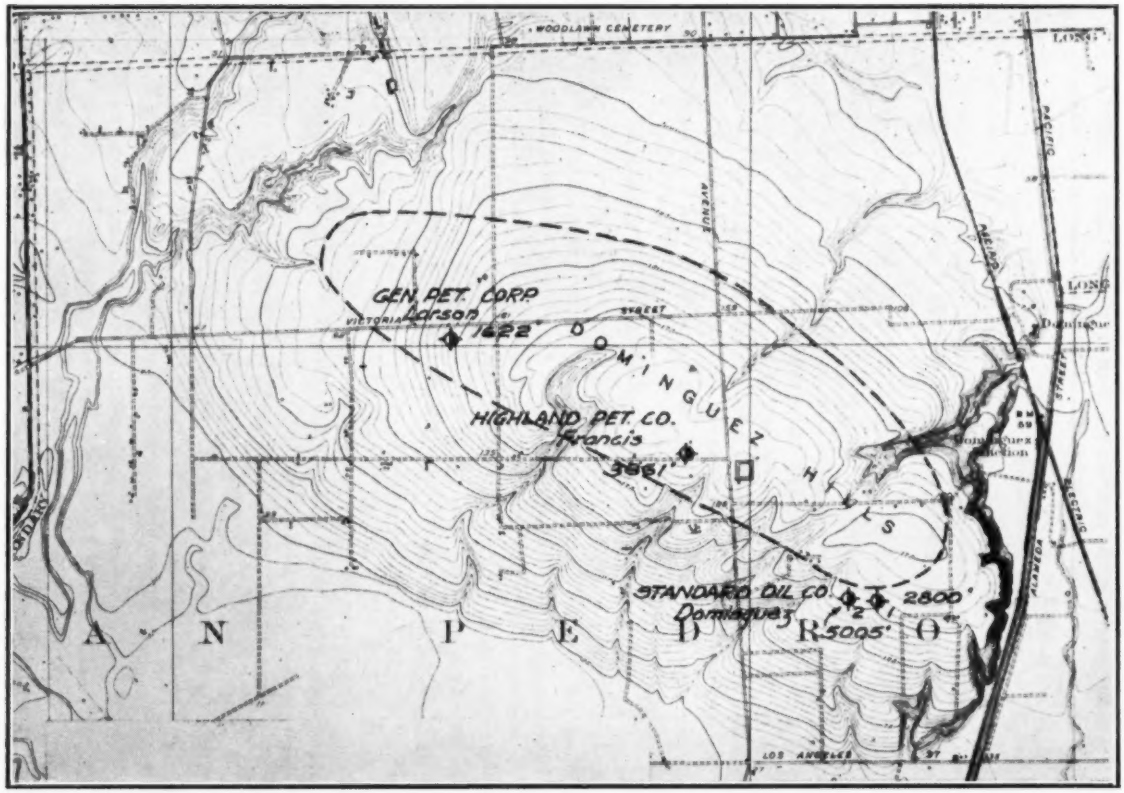

FIG. 3.—Dominguez Hills, showing location of early test wells (depth in feet), with present outline of productive area indicated by broken line. Topographic contour interval, 5 feet.

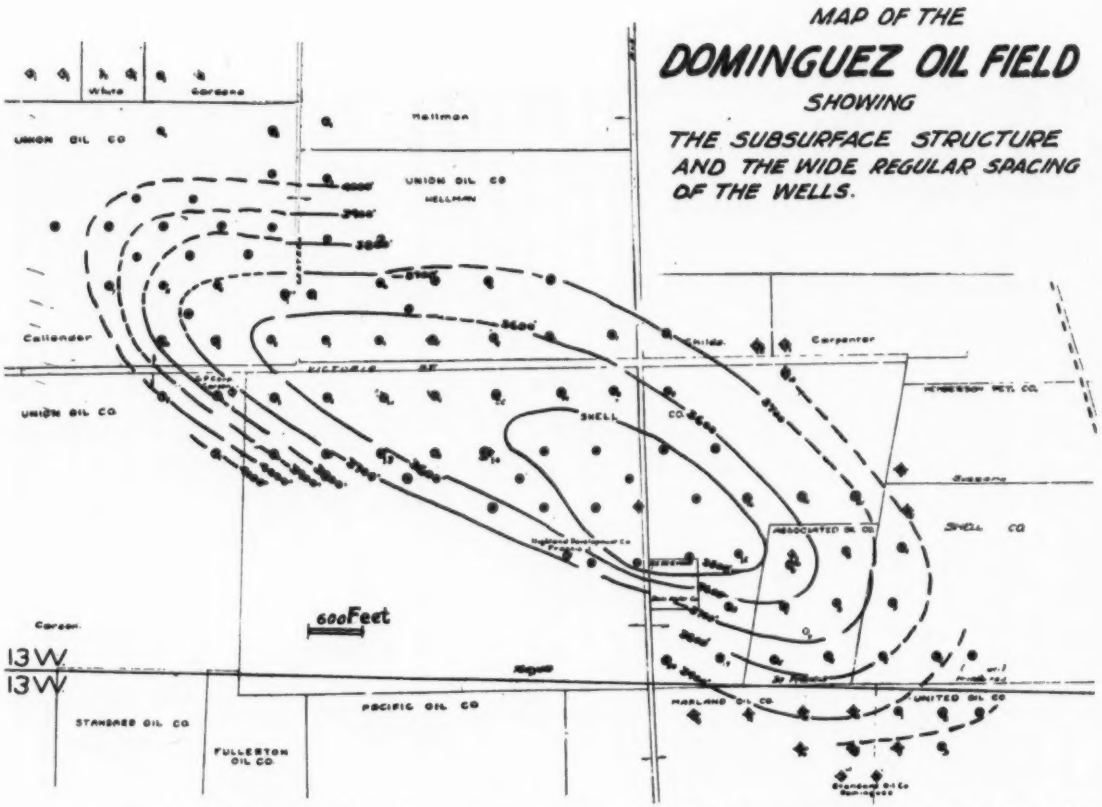

FIG. 4.—Map of the Dominguez oil field. Contour interval, 100 feet. Subsurface contours on top of the Callender zone, which is the producing zone, in feet below sea-level.

Despite the fact that these wells were drilled so far apart, so that one might feel that well interference would not be very great and that the time of drilling would not be an important element, the following comparison shows the effect of time of completion: a well completed on December 10, 1924, had an initial production of 3,100 barrels, and a well completed March 5, 1925, an initial production of 800 barrels. Both of these wells were located on the most favorable part of the structure. Average initial production of all wells completed, by years, was as follows:

1924	2,749 barrels
1925	1,251 barrels
1926	460 barrels

The indicated average ultimate production per well for the wells completed, by years, will probably be as follows:

1924	771,977 barrels
1925	398,843 barrels
1926	290,462 barrels

One other interesting feature emphasized by developments in this field and related to the spacing of the wells is the fact that for wells penetrating 400 feet of oil zone, the interior wells distinctly do not show the same recovery, even when completed at the same time, or at an earlier date, and with the advantage of structural position, that the wells show which are on the outer rim of the developed area where they are benefitted by unrestricted drainage without the interference of other wells beyond them. In order to make a comparison, the total estimated ultimate production of the wells in barrels and their dates of completion are given.

INNER WELLS		OUTER WELLS		
Date Completed	*Total Ultimate Production*	*Date Completed*	*Total Ultimate Production*	*Outer Wells' Advantage*
6/22/24	658,430	7/13/24	1,395,570	737,140
12/23/24	361,926	12/ 9/24	907,310	545,384
12/23/24	773,028	12/10/24	1,190,072	417,044
12/18/24	856,823	11/24/24	1,066,835	310,012
11/29/24	453,983	12/ 5/24	552,188	98,205

Twelve outer-rim wells were completed prior to the end of 1924; seven of these will have an ultimate production of more than one million barrels per well. Eleven inner wells were completed prior to the end of 1924, but probably not one of these will have an ultimate production of a million barrels.

The oil produced in the Dominguez field is of much the same character as that produced in the Signal Hill and Huntington Beach fields.

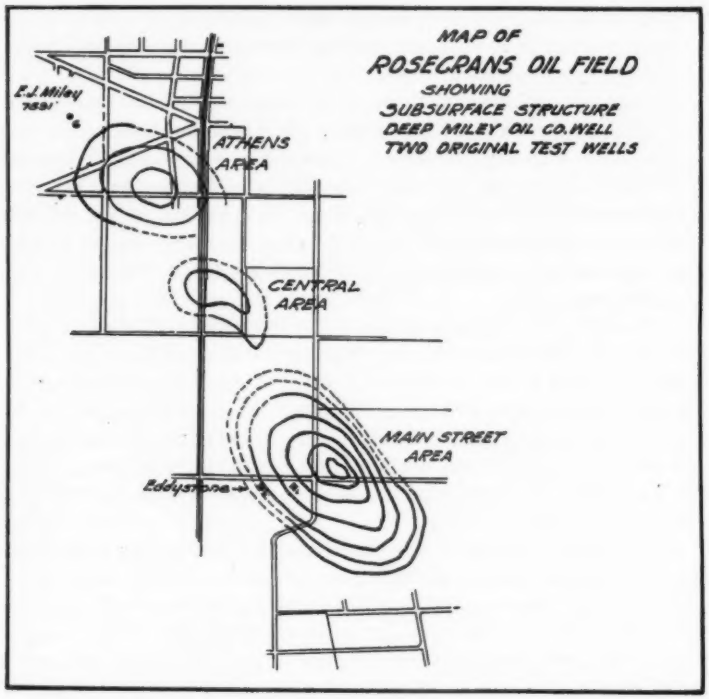

FIG. 5.—Map of Rosecrans oil field. Contours sketched to show relative subsurface reliefs of the three small domes of the top of the upper producing zone. Contour interval in the Main Street area, 100 feet; in the other areas, 50 feet.

Figure 5 sketches the comparative subsurface structure of the Rosecrans oil field. It brings out in somewhat too prominent relief the location of the Eddystone No. 1 and No. 2 wells, which were the original tests in this district that failed. These wells were drilled in 1919 and 1920 and found oil and gas. Had the operators known what has since been proved and established by the core barrel they probably would have secured commercial production in the No. 1 test well. At Rosecrans the oil is of such light gravity that only the experienced petroleum engineer who has handled many cores in the field is able to appreciate the significance and importance of an ether test on core-barrel samples. The oil varies in gravity from 36° to 42° Bé. The sands, even when oil-bearing, are gray in color. Their smell when freshly taken from the core barrel

is quite as important in determining their oil-bearing character as is the cut secured, but none of these facts was known by the original drillers of the Eddystone wells.

In 1922 the Potter Oil Company drilled a well in the Athens area to a depth of 4,520 feet, without finding oil. Operations were suspended but the leases were not quitclaimed. Following the success in the Dominguez field in the fall of 1923, the Union Oil company felt that a new test near the Eddystone wells was warranted. As a result it drilled the discovery well in the Rosecrans area in 1924 and took over the Potter well and deepened it so that the Potter well also became the discovery well of the Athens area.

The oil in the Rosecrans field is found at a depth as shallow as 3,600 feet, but the main commercial production lies at depths ranging from 4,000 to 4,900 feet, in the various small domes that make up this field. In some parts of the field the oil zone is as much as 500 to 700 feet thick.

Wells widely spaced in this field have produced more than 500 barrels per day for a year. During the time that the oil in this field was selling for more than $2.00 per barrel such wells were undoubtedly the best revenue producers in the state.

The Rosecrans field is also of interest because in this field E. J. Miley drilled the deepest producing oil well in the world in 1925, completing it at a depth of 7,591 feet. The fact that one other well has since been drilled to 8,046 feet does not lessen the credit due Miley because his was the first pioneer effort with rotary tools. Cable-tool wells in the east had reached nearly as deep as the Miley well.

The Rosecrans field also has the deepest oil-bearing formation in the Los Angeles basin, lying at depths in excess of 7,000 feet. This is even below the deepest oil formation found thus far by the recent development work in the Long Beach field. The oil formation is not nearly so productive, however. The Rosecrans field was the scene of intense town-lot activity in the Athens area and most of the wells drilled there failed to pay. At the present time an oil sand at 5,600 feet is being developed in a minor way.

By far the most prominent topographic feature in the Palms-to-Newport uplift is the Baldwin Hills. For this reason they invited prospecting in 1917 by the Bartola Oil Company and in 1918 and 1919 by the Standard Oil Company. None of the wells found oil, although they were deep tests and were located on or near the top of the surface dome. The presence of a gas seepage in the northwest end of the hills caused the 57 Petroleum Corporation to drill a test there. In 1923 the Pacific

Oil Company drilled a test well north of the hills, on the theory that part of the structure had been eroded. None of these failures was sufficient to dispose of the conviction held by many geologists and oil operators that these hills contained an oil field. Thus it was that the test well which proved successful was begun by the Standard Oil Company in March, 1926. In less than two weeks, the well had found oil sand at a shallow depth and was subsequently completed as a commercial producer of the Inglewood oil field. The key to past failures lay in a fault zone which crosses the hills. Proof of its existence was established by surface work and also by drilling. In the light of subsequent developments it is rather surprising that these features were not so thoroughly appreciated before the field was developed as they were afterward.

Figure 6 shows the underground structure which was developed by drilling and also the fault zone. This drilling shows that the fault was subsequent to the formation of the anticline and the accumulation of the oil. The northeast side of the fault was lifted with respect to the southwest side so that the high topography was actually the flank of the underground structure. The lower topography concealed the crest of the structure.

Figure 7 is an ideal east-west cross-section through the field, showing the relation of the Pleistocene to the Pliocene and the upper and lower oil zones and the relation of the fault to the structure. This cross-section also brings out the fact that while the upper oil zones have been thoroughly exploited, there lies beneath this field an additional oil zone which is 400 to 500 feet thick. The upper zones have produced oil varying in gravity from 15° to 23° Bé., but the lower zone will furnish oil varying in gravity from 22° to 28°. One well has been flowing from this zone since 1925. Another well was drilled into the zone but has been shut in since 1926.

It is also of interest to point out that the beds down the dip that were elevated by the fault contained oil of lighter gravity on the northeast side of the fault than do the beds in the fault zone and immediately southwest of it. Differences of 2° to 4° gravity have been noted.

Figure 8 of the Huntington Beach field shows the outer limits of the uplift and the structure thus far developed, as well as the productive area in 1923 (the main field and Barley Flat). The structure of the main field proved to be monoclinal. Production in the northwest end was still good in 1923, but at the southeast end of the main field the oil sand, for no particularly good reason, seemed to merge into gray sands. An additional interesting feature was the production of oil secured in what was called the Barley Flat, southwest of the main field. Develop-

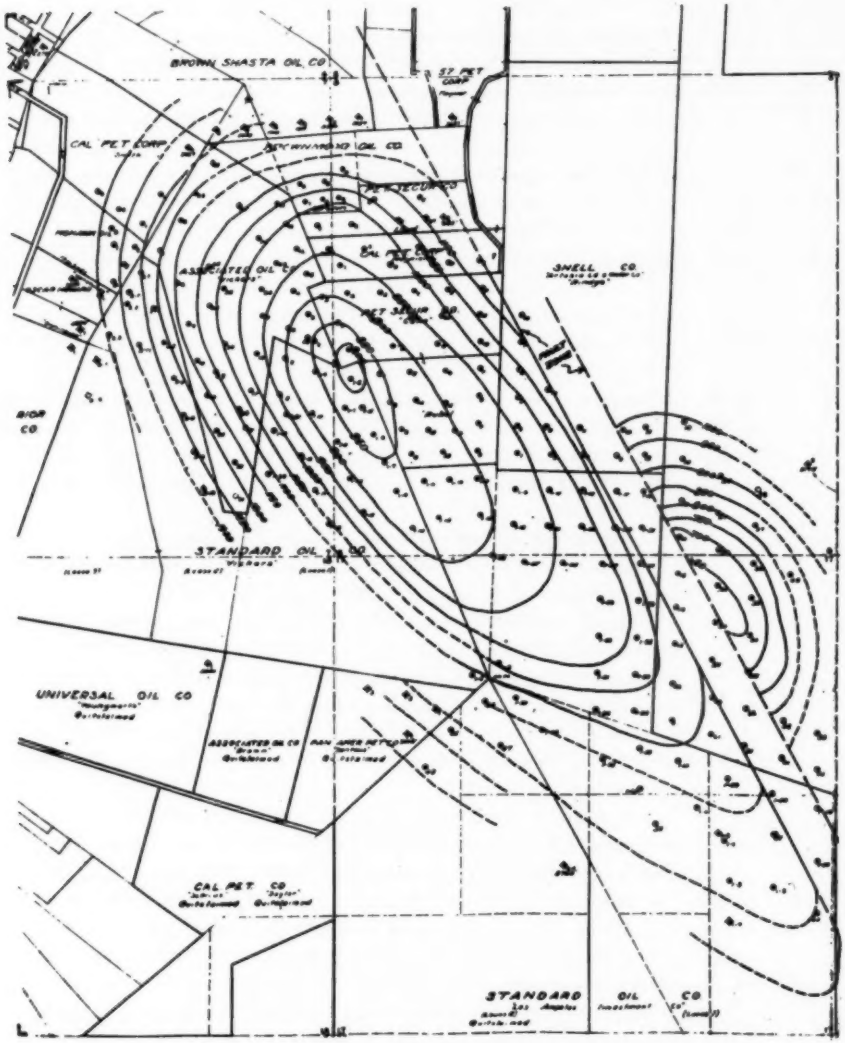

FIG. 6.—Subsurface contour map of the Inglewood oil field (Vickers zone). Contour interval, 50 feet. Contours show depth in feet below sea-level to the top of the Vickers zone, which is the upper producing zone.

FIG. 7.—Ideal west-east section through the Inglewood oil field showing relation of Pleistocene to Pliocene sediments and upper and lower oil zones with edge-water sands; also relation of fault to structure.

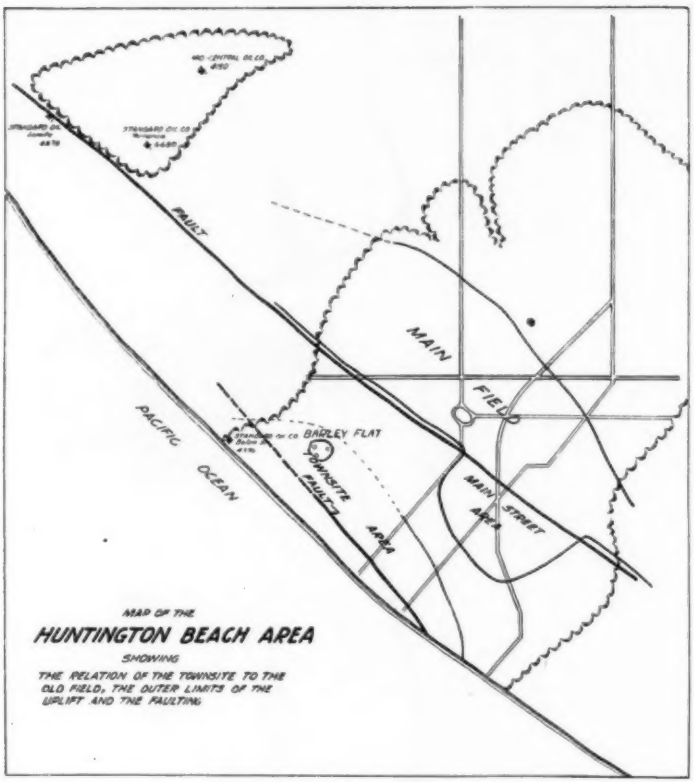

FIG. 8.—Map of Huntington Beach. The main field and Barley Flat were productive in 1923.

ment in the Barley Flat was not pushed intensively by the Standard Oil Company, but in November, 1925, a 500-barrel well was secured near the ocean. All of this land on the Barley Flat was under lease to the Standard Oil Company. The Huntington Beach townsite area lay to the southeast, in a line parallel to the trend of the main field. Drilling restrictions in the city prevented activity. These were finally lifted in the spring of 1926. By December, 1926, the town-lot field had been fairly well drilled and a peak production of 61,000 barrels had been established.

Drilling disclosed the fact that faulting played a part in the existence of this field. Attention is called to the townsite fault in the townsite area. Emphasis is also placed upon the fault extending in front of the main field. This fault probably accounts for the monocline in the main field. The relationship of the district between the main field and the townsite area has not been fully worked out. Even the position and the relationship of the townsite fault are not fully accepted by all engineers.

Aside from the importance of faulting, the most interesting feature of the developments in the townsite area is the fact that much oil is secured in the Miocene formation. The production of the main field is from the Pliocene. Consequently the district northeast of the main fault must have been lowered, while the district in the vicinity of the townsite was raised.

Figure 9 of the Seal Beach area shows the outer limits of this uplift and the test wells drilled before the field was discovered. At that time one group of geologists held that the topographic feature at Alamitos

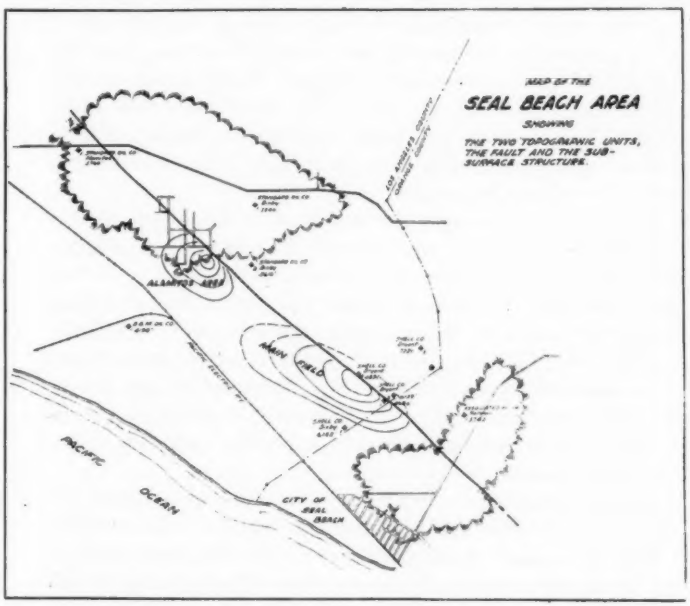

FIG. 9.—Map of Seal Beach. The wells shown were the test wells drilled before the field was discovered.

Heights and the Hellman Hill at Seal Beach represented a single topographic uplift that had been cut apart by San Gabriel River. They therefore felt that if an oil field existed in the district it would probably lie farther west than the test wells that had been drilled close to the county line between Orange and Los Angeles counties. Figure 9 also shows developments which have occurred since it has been proved that there is a main field at Seal Beach and also one at Alamitos Heights. Unquestionably the presence of two structures here instead of one is one of the most interesting developments in the field. The fact that a fault parallels the strike of the fields is of somewhat minor interest. While the northeast side of the fault in the Inglewood field was lifted, the northeast side of the fault in the Seal Beach field is the down-thrown side.

On the crest of the structure in the main part of the Seal Beach field the main oil zone is probably 640 feet thick. There may be an intermediate edge water that will separate this zone from another one of considerable but as yet unknown thickness. Parts of this upper 640 feet have been given several names. More recently beneath all of this oil zone a deeper sand in the Miocene formation has been found by the Marland Oil Company at Alamitos Heights. The presence of Miocene beds has been proved in the main field, but the test well which found them did not penetrate far enough to dispose of the question as to whether or not the Miocene oil of Alamitos Heights will be found in the main field. It is reasonable to expect that it will.

The most important factor in the present oil situation in California is the Long Beach field. The importance of this field was not fully appreciated in 1923. This is shown by the fact that it failed to decline materially in production, even in 1924, and that a great deal of drilling in the northwest end of the field was done throughout 1924. This activity continued into 1925. By the end of that year it almost appeared as though a companion structure had been found northwest of Long Beach. This relationship was established by development. The new area known as Los Cerritos proved to be only an extension of the main field. The relation between the two is shown in Figure 10.

The drilling campaign at Los Cerritos was well under way at the beginning of 1926. The oil-bearing formations proved to be only about 100 feet thick at a depth of 4,300 feet and 70 feet thick at a depth of 4,800 feet. The securing of 2,500-barrel wells in the beginning of this development led to town-lot drilling, which proved most disastrous. About 160 producing wells were secured, but more than one-third of these

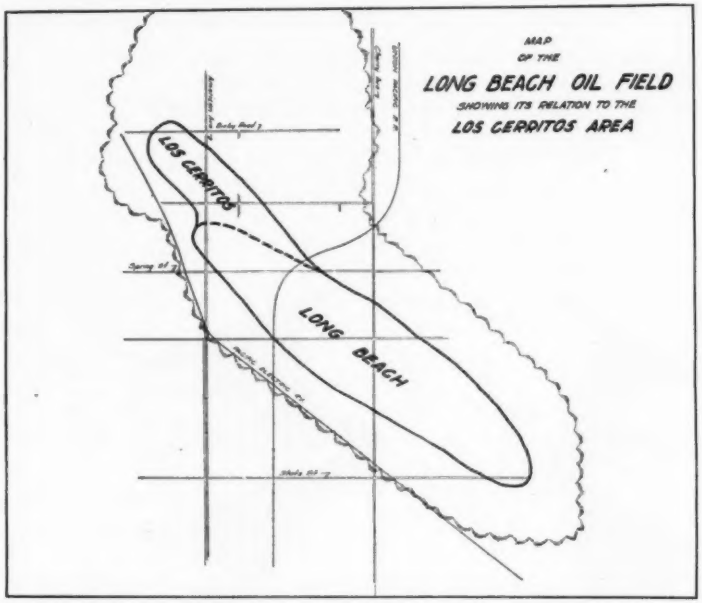

FIG. 10.—Map of the Long Beach oil field.

have been abandoned, while the average production of the 100 that remain is now only 34 barrels per day.

The new production which is coming from the Long Beach field is from the main field in a zone which has been known since 1923 and 1924. Figure 11 is an ideal north-south section through the Long Beach field, showing the relation of the newly-developed deep zone to the earlier productive zones. The Alamitos zone was proved to be 950 feet thick. Along the crest of the structure the Brown zone, 1,800 feet thick, was found without any intervening water, giving a total of 2,750 feet of oil-bearing formation. Off the crest of the structure several edge waters interfered with penetration of these great thicknesses of oil zone, but many productive wells were secured. The heavy broken line on Figure 11 shows the depth to which a few wells were drilled on the crest of the structure. The presence of edge water at the base of the Brown zone stopped the drilling of many wells below this edge water, which was often considered bottom water.

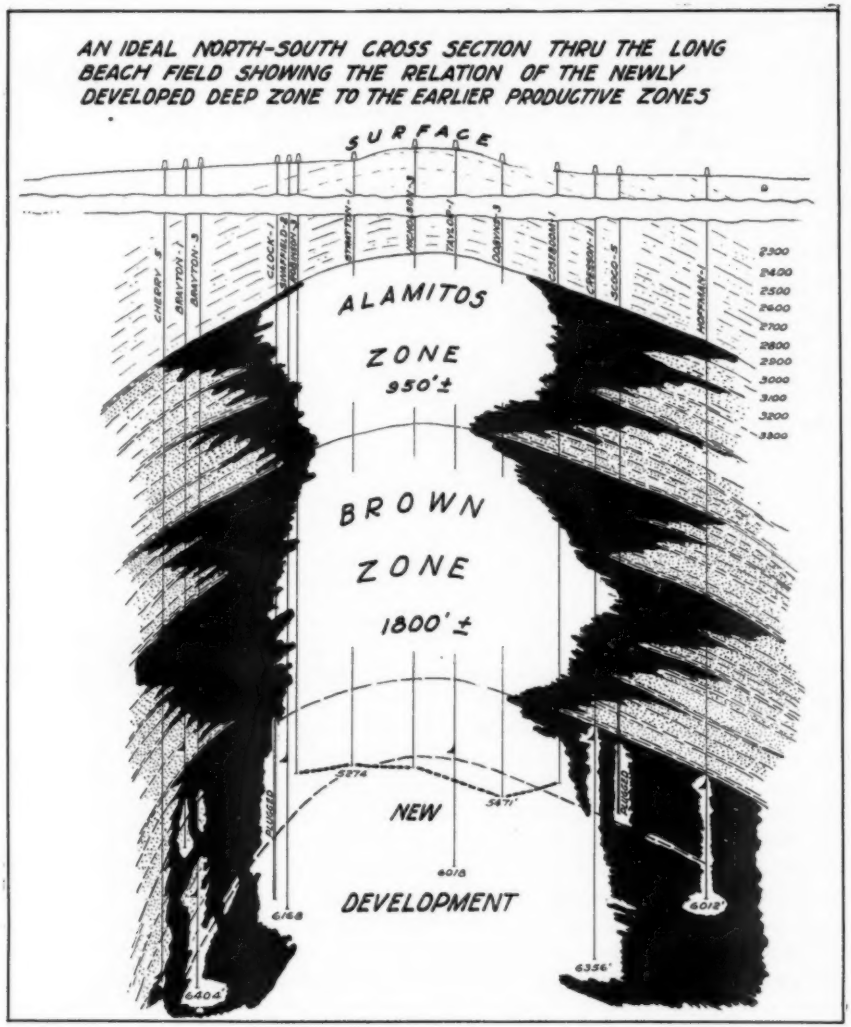

FIG. 11.—Ideal cross-section through the Long Beach field. Depths shown in feet

Beginning in the latter part of 1926 and extending through 1927 wells were drilled progressively deeper into the deep zone beneath this intermediate or edge water at the base of the Brown zone in the northwest end and also the southeast end of the field. These wells resulted in securing several 3,000- and 4,000-barrel wells. By October, 1927, the importance of this deeper oil zone was fully appreciated by all operators in the field. Since that time an intensive drilling campaign has been under way. There are now 44 deep-zone wells producing 54,636 barrels, representing an average of 1,240 barrels per well. The total operations in the field number 238 and there are in addition 44 idle wells, represented by rigs, dry holes, and water wells. Of the 238 operations, only 29 are not actually drilling and these vary from rigs to wells rigging up.

The rate of increase of this new production has not been fully appreciated because of the fact that it is lumped with the production of the Long Beach field. The total production of the field has declined, due to wells being deepened and due to the natural decline of production. On November 3, 1927, there were only 8 deep-zone wells, producing 15,234 barrels. By January 5, 1928, there were 24 deep-zone wells, producing 39,103 barrels. It thus appears that in the last two and a half months only 20 deep-zone wells have been completed and only 15,500 barrels of new production has been secured. Despite this slow rate of increase it is interesting to point out that the new wells drilling may be classified as follows:

NEW WELLS DRILLING AT LONG BEACH

Drilling above 4,000 feet	55
Drilling 4,000 to 5,000 feet	37
Drilling 5,000 to 6,000 feet	37
Drilling below 6,000 feet	10
Below the water shut-off	17
Preparing to complete	4

Old wells that are being deepened are classified as follows:

OLD WELLS BEING DEEPENED, LONG BEACH

Deepening above 5,000 feet	7
Deepening 5,000 to 6,000 feet	29
Deepening below 6,000 feet	6

Within the past ten days one well has been completed so as to yield at the rate of 3,700 barrels per day. This is due to the fact that it penetrated into the oil zone about 150 feet deeper than near-by wells.

The new zone of deep development has now been proved nearly 1,200 feet thick, and its maximum thickness has not yet been established on the crest of the structure.

More than half of the operations in the field are under the control of financially strong operators. Generally speaking, the wells now drilling will be drilled to completion and not abandoned. Nevertheless, it is interesting to note that 11 new wells and 12 deepened wells are already idle because of mechanical or water conditions. This is more than one-half the number of producing wells. These facts indicate that while the peak of production of the Long Beach field has been somewhat delayed and probably will be delayed until May, there will nevertheless be produced during 1928 an immense volume of oil from this new deep zone. The Long Beach field proper covers 800 acres. The zone ranges in thickness from 400 to 1,200 feet. Obviously, these two factors promise a sustained volume of oil that will contrast very markedly with the flash peaks at Alamitos Heights in 1927, when as much as 55,000 barrels per day was produced from 60 acres of land.

From a geological standpoint the most interesting feature of this deep-zone development is the fact that the new oil comes principally from the Miocene formation. Since 1923, the Miocene has been proved a source of oil in the Richfield, Huntington Beach townsite, Seal Beach, and Long Beach fields. It has been proved non-oil-bearing in the Torrance and Beverly Hills oil fields.

Deep tests in the Santa Fé Springs field, carried to 6,099 and 7,103 feet, failed to find deeper oil. Likewise, in the Fullerton field deep tests to 5,500 feet that probably reached the Miocene found no deeper oil. This finding of oil in the Miocene leads to the expectation that some of the other fields will also furnish Miocene oil. On the other hand, it must also be borne in mind that the identification of the Miocene rocks has been made since 1923 and that if material were available from some of the older fields it might prove that these fields also are producing from the Miocene. This apparently is true in the old Salt Lake field.

Two interesting geological facts have been brought out in the development of these fields during the past five years, the bearing of faulting on the topography, and the occurrence of oil in the Miocene.

Figure 2 shows how fully the Palms-to-Newport uplift has been proved the seat of oil fields, and also shows that, with the exception of the Potrero district, every uplift has now been proved to represent an oil field. Two faults are associated with this uplift. The upthrown side of the one on the northeast side of the Inglewood field is the northeast

block; the up-thrown side of the one in the vicinity of the Seal Beach field is the southwest block.

The fact that faulting had an important bearing on developments in the Inglewood field has already been emphasized. That it might have a bearing on the next uplift to the southeast was sensed about two years ago, and this led to renewed prospecting in the Potrero district. Figure 12 shows the south portion of the Inglewood field and the Potrero district, as well as the relation of topography to faulting. Figure 13 shows the wells that have been drilled in the Potrero district, as well as the approximate position of the fault scarp. Thus far, gas has been found in two wells, both of which lie east of the fault—the one being Standard's Farrell No. 1, in Section 27, and the other, California Eastern's Smith No. 1 in Section 35. An oil-bearing formation has been found in the Associated's Cypress No. 1 in Section 34, from 4,383 to 5,408 feet. Such production as has come from the well is oil varying from 37° to 40° Bé. gravity, and this well has produced as much as 130 barrels of clean oil per day.

The Associated's Cypress No. 2 is also drilling in Section 34.[1] It has found the same shallower oil showings at approximately the same depths below sea-level as Cypress No. 1, but it has not yet reached the zones from which Cypress No. 1 produced. In this district oil showings have, therefore, been proved through a vertical thickness of about 1,000 feet and they have been proved horizontally about 900 feet. The character

[1]SUBSEQUENT NOTE, APRIL 20, 1928.—The well was drilled to a total depth of 4,619 feet and the 9-inch casing was cemented at 4,421 feet. On April 11, 1928, it was swabbed at 8:00 A. M. through 3-inch tubing hung at 3,994 feet. The well started to flow at 12:56 noon at an estimated rate of 1,000 barrels per day. By 6:30 P. M. the oil showed a gravity of 47.5° and a total cut of 2.3 per cent. The well was turned into the tanks at 10:40 A. M. on April 12. Thereafter the following information was obtained:

Date	*Barrels Production*	*Degrees Gravity*	*Cut*	*Pounds Tubing Pressure*	*Pounds Casing Pressure*
4/12/28	1,049	47.2	2.9	110–300	500–680
4/13/28	947	43.4–47.9	5.0	15–375	400–750
4/14/28	965	45.7–48.2	4.0	90–275	480–750

The well was shut in at noon on April 15 on account of lack of storage. Sample of oil as tested showed a gravity of 48.6°, B. S. & M. 1.2 per cent, 437 E. P. gasoline 74.52 per cent, four point gasoline 70.50 per cent, sulphur 0.33 per cent. The estimated flow of gas was from 750,000 to 1,750,000 cubic feet per day. The gasoline content by ether, carbon dioxide, and ice alcohol test averaged 3.2 gallons per thousand cubic feet.

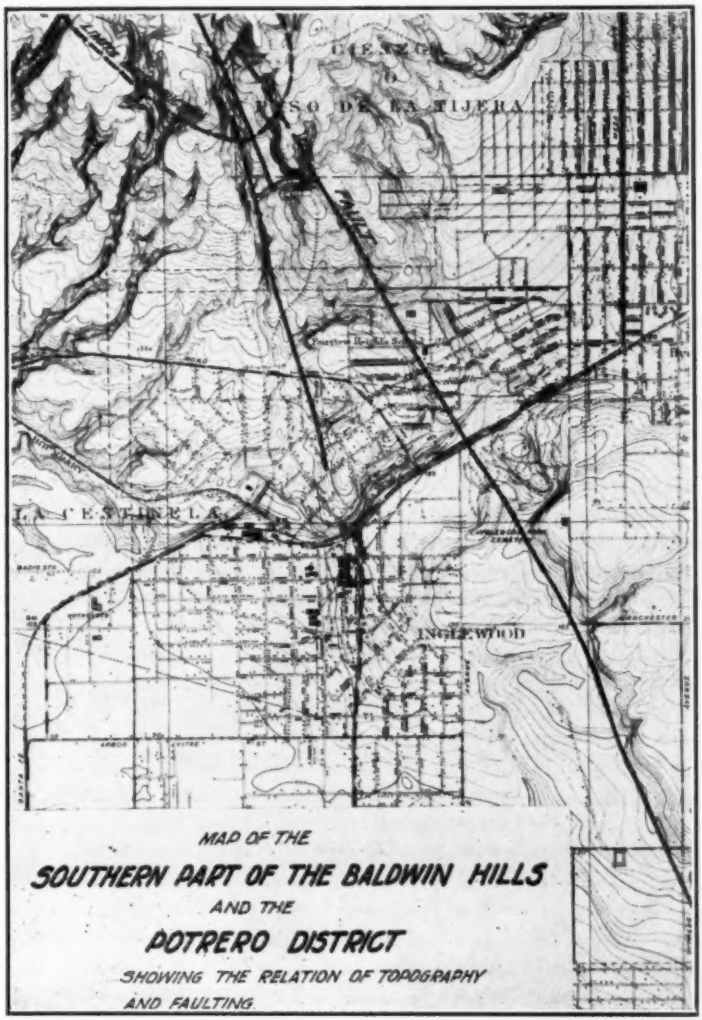

FIG. 12.—Map of the southern part of the Baldwin Hills and the Potrero district. Topographic contour interval, 5 feet.

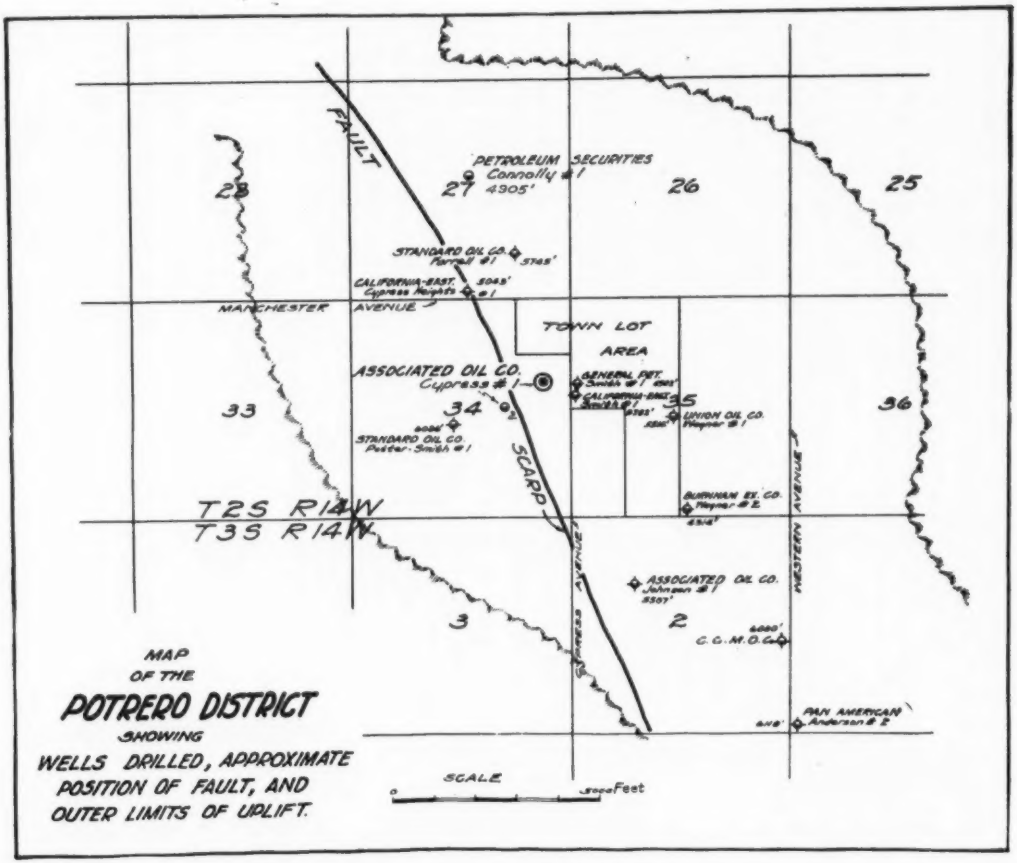

FIG. 13.—Map of the Potrero district.

of oil and the formations secured in the Potrero district indicate that if a field is found it will be very similar to the Rosecrans field. Experience in the development of that field has indicated the sort of problems that may be expected in further work in the Potrero district.

One may well ask what the future of the Los Angeles basin will be. Figure 1 shows the abandoned wildcats in the Los Angeles basin. They are so numerous that it is hard to find an area which has not been prospected. Experience in the development of the Torrance field indicates, however, that the sand-dune area northwest of it and south of the Inglewood field may possibly furnish an oil field. Some oil has been found and drilling activity has not ceased.

The Miocene formation beneath some of the other older fields may result in new discoveries. In addition to this fact the presence of commercial oil zones has been established in the Inglewood, Rosecrans, and Dominguez fields. Fortunately, no intense activity is planned for these fields during the year 1928. The activity in Long Beach promises to be sufficient to furnish more than enough oil for California's present needs.

Perhaps the most important lesson that the geologist may take from the developments that have occurred in Los Angeles fields is the assurance that the fundamentals of geology may well be respected, even though the physical and mechanical developments based upon these ideas may temporarily fail. In the application of a science to an immensely valuable district, which application after all depends so much upon personal conviction and courage and faith in one's understanding of the facts available, it is highly gratifying to note the soundness of the geological work done and the value of the results achieved by it in the development of the Los Angeles basin oil fields.

THE CALIFORNIA OIL INDUSTRY IN 1927[1]

AUSTIN CADLE[2]
San Francisco, California

ABSTRACT

The writer first discusses the economic relationship between the supply of and demand for petroleum in the California district. On a daily basis, during 1927, about 665,000 barrels of crude and casinghead gasoline were produced, an additional 70,000 barrels were shut in, and the total petroleum demand was 686,000 barrels, resulting in a net decline in total stocks of 21,000 barrels, or 7,500,000 barrels for the year. The largest decline was 12,629,000 barrels in stocks of light crude and tops, whereas heavy crude and fuel oil showed an increase of 5,161,000 barrels.

The writer further discusses the important production and geological features of the new developments in California. The Huntington Beach and Seal Beach fields, in addition to the volume shut in, were the principal factors influencing total production in 1927. Long Beach is likely to be the major factor in 1928. New areas discussed include Alamitos Heights, Rincon, Goleta, Potrero, and the important developments in the southern end of the San Joaquin valley, namely, Mt. Poso, Round Mountain, Union Avenue, Edison, Fruitvale, and Buttonwillow.

There are many features of the oil industry, other than those of a geological nature, which should prove interesting to any group of petroleum geologists. Among these, one of the most vital to our activities is the economic relationship between supply and demand. It is the purpose of the writer to briefly analyze this situation as it existed on the Pacific Coast during 1927, and to give a brief survey of new production developments in California.

PART I. SUPPLY OF AND DEMAND FOR PETROLEUM IN THE CALIFORNIA DISTRICT

CONSERVATION

The outstanding feature of the production situation in California during 1927 was one of true conservation effected through shutting in production. An average for the year of approximately 77,000 barrels per day was withheld in nature's reservoirs. On a 10 per cent decline basis, this figure would be reduced to about 70,000 barrels and had this amount been produced throughout the year, approximately 18,000,000 barrels would have been added to storage in this district. As a matter of fact, withdrawals from all stocks amounted to more than 7,500,000

[1]Read before the Association at the San Francisco meeting, March 21, 1928.

[2]Petroleum geologist, Standard Oil Company of California.

barrels. In every year since 1921, a large volume of production has been withheld in this manner. At the present time, operators are coöperating with State officials on a plan to shut in an additional 70,000 barrels of oil and a large volume of gas.

TOTAL PRODUCTION AND CONSUMPTION

The heavy line on Figure 1 shows actual crude and casinghead production in 1926 and 1927, the area between this and the broken line representing the volume of oil shut in. It should be noted that the production curve showed a slight decline during the year 1927, whereas total demand (shown by the light line) increased 5 per cent over the year 1926. The net result of these conditions was the 7,500,000-barrel withdrawal from stocks. The areas between the light and heavy solid lines which are above the heavy line are an approximate indication of the amount of withdrawals with the dark shaded areas indicating additions to storage.

PRODUCTION

Crude production in 1927 averaged 632,000 barrels daily. The Huntington Beach, Seal Beach, and Long Beach fields, in addition to the volume shut in, were the major factors influencing movements of total production (Fig. 2).

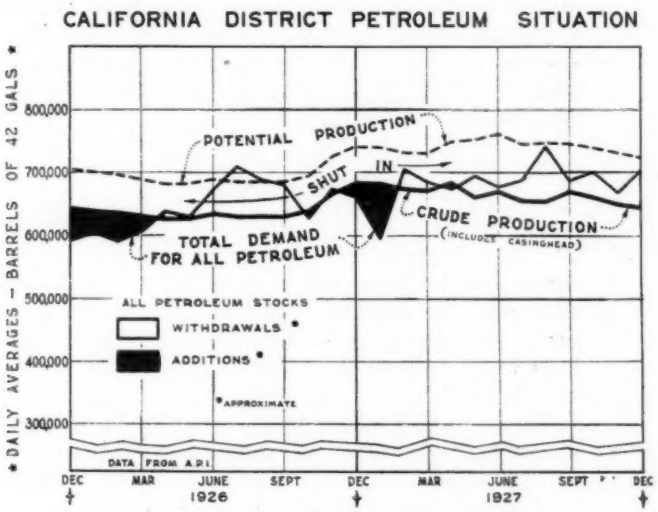

FIG. 1

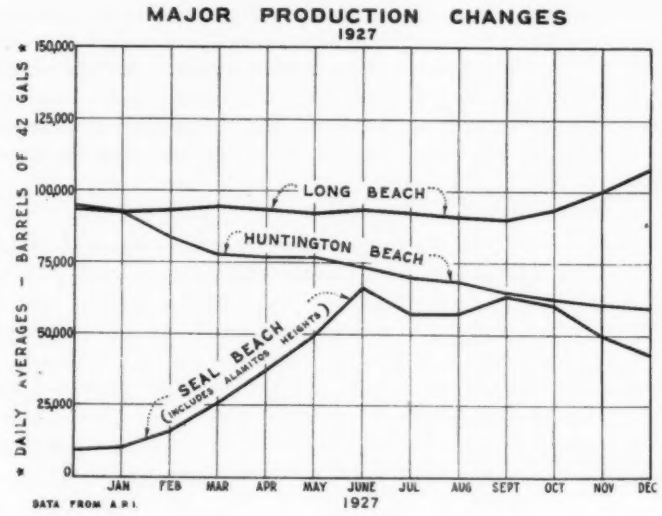

FIG. 2

The Huntington Beach field, as shown on the chart, declined from a production of more than 90,000 barrels daily in January to about 60,000 barrels by the end of the year. The Seal Beach peak, of 66,000 barrels daily, due largely to the town-lot drilling at Alamitos Heights, came in June, a rise of 56,000 barrels over January. This field then declined to about 42,000 barrels per day by the end of the year. The trend of Long Beach production is likewise depicted and this field is expected to be the major source of new production during 1928. It may be noted that its production rose from about 90,000 barrels daily in September to about 108,000 barrels by the end of the year. Early in March, 1928, it had reached 119,000 barrels, of which 55,000 barrels was being produced from 45 wells in the deep sand. Estimates for the peak in this field, which should be reached about the middle of the year, range around 175,000 barrels daily.

CONSUMPTION

The total demand for all petroleum products averaged 686,000 barrels daily for the year. About 65 per cent was consumed in California district markets, the balance consisting of Pacific exports and Canal shipments. The domestic demand for gasoline throughout the California

district averaged almost 100,000 barrels daily, an increase of 13 per cent over the previous year. Large increases occurred in shipments of gasoline to Australia and New Zealand, the expansion of business in these markets being the outstanding feature of the Pacific export trade. The total demand for fuel oil was 429,000 barrels daily, 87 per cent of which was consumed in the western states and by markets bordering the Pacific Ocean.

STOCKS

Total stocks reached a high point of 160,400,000 barrels in March, 1926, and the following month serious fires caused losses totaling 8,200,000 barrels (Fig. 3). Since then, total inventories, in general, have declined, such a decline being made possible largely through shutting-in operations by California companies. Stocks at the end of December, 1927, stood at 139,340,000 barrels. Inventories of light crude and tops have declined very appreciably since early in 1926, concurrently with a rise in stocks of heavy crude and fuel oil. In 1927 light stocks declined 12,629,000 barrels and heavy stocks increased 5,161,000 barrels.

PART II. SURVEY OF NEW FIELDS

Numerous new fields and promising areas have recently been discovered or developed in California. The exploitation of most importance

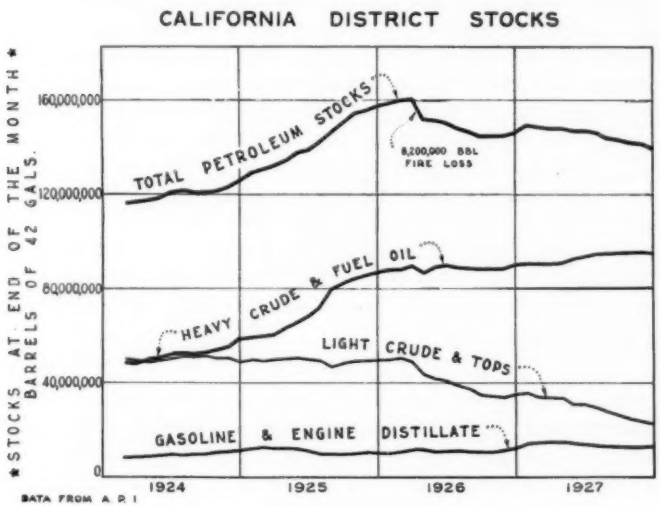

FIG. 3

to production during 1927 occurred in the Alamitos Heights town-lot area at Seal Beach. The development of deeper sands in the old Long Beach field indicates a large output for the year 1928, and the Rincon field at Seacliff in Santa Barbara County also has good potentialities. Ventura Avenue was extended more than a thousand feet southwest and a similar distance eastward. Other areas which have witnessed activity are Mt. Poso, Round Mountain, Edison, Union Avenue, Fruitvale, and Buttonwillow districts in the southern end of the San Joaquin valley, Rincon and Goleta along the coast, and Potrero in southern California.

ALAMITOS HEIGHTS

At Alamitos Heights 160 wells were drilled in an area of only 83 acres, this being a good example of excessive drilling due to town-lot competition among property owners. The remainder of the Seal Beach field, southeast of Alamitos Heights, has been conservatively developed. A deeper producing horizon lying below 6,000 feet has been discovered which may result in increased production, although only four wells have been completed to date with initial yields from 500 barrels to 1,000 barrels.

Alamitos Heights is one of the fields associated with the Newport-to-Beverly Hills fault zone, and a major fault trending northwest and southeast cuts across the northeastern part of the field. Production is obtained mainly at depths from 4,600 to 5,500 feet, from the lower part of the Pico member, which is in the Fernando group of Pliocene age, and possibly also extends on down into what has been called the Intermediate zone or even to the upper beds of the Miocene. The Fernando includes the principal productive formations of the Los Angeles basin fields.

LONG BEACH

There are about 250 deep-sand operations under way with almost 100 wells drilling below 5,000 feet. Deep-sand wells range in depth from 5,600 to 6,400 feet and the areal extent of this horizon is expected to be similar to that of the older producing sands which at present cover 1,600 acres.

RINCON (SEACLIFF)

The Rincon field is situated on a westerly extension of the Ventura anticline, where this anticline meets the Pacific Ocean some 8 miles northwest of Ventura. Production is stratigraphically higher than that at Ventura Avenue and is obtained from the Pico member of the Fernando group at depths around 2,800 feet. There were two wells in the

field early in March producing a total of 400 barrels daily with twelve drillers under way. The results in this field have been disappointing in the upper sands where water was found closely associated with the oil, and attempts to develop deeper production are likely to be made. The gravity of the oil is about 30° Bé., practically the same as the gravity of the oil at Ventura Avenue.

GOLETA

Goleta is the farthest west of the coastal fields adjacent to Ventura, being situated about 16 miles west of the production at Summerland. Results in this field have been disappointing, only one well out of nine being a producer of any consequence. Production is obtained at a depth of about 1,300 feet from sands in the Sespe formation of Oligocene age. Some development has also taken place westward along the Edwards anticline, where small production was obtained.

POTRERO

The Potrero field lies between the Inglewood and Rosecrans fields in southern California. Some oil was produced here during September, 1927, when about 200 barrels daily of 39° Bé. gravity oil was obtained as an initial flow from 4,400 feet. Since that time, however, the well has been off production and has had much trouble. A second well is now being drilled by the same company. Numerous operators have tried for years to obtain commercial production in this area and several new tests are now planned.

SAN JOAQUIN VALLEY

The southern end of the San Joaquin valley has been the scene of much leasing and wildcat drilling within the last few years. This activity has resulted in the discovery of five new or prospective fields—Mt. Poso, Round Mountain, Union Avenue, Edison, and Fruitvale, the last three being still in very early stages of development. The Union Avenue and Fruitvale areas lie several miles out in the valley from the hills east of Bakersfield. They are situated along the Bear Mountain fault zone which trends approximately northwest-southeast. The expression of their structures in the topography is very slight. The sketch map of the area around Bakersfield (Fig. 4) shows the relative location and principal geological features of these important areas. Discovery of oil out in the valley is tending to revise the ideas of many geologists as to the future possibilities for production under the valley floor.

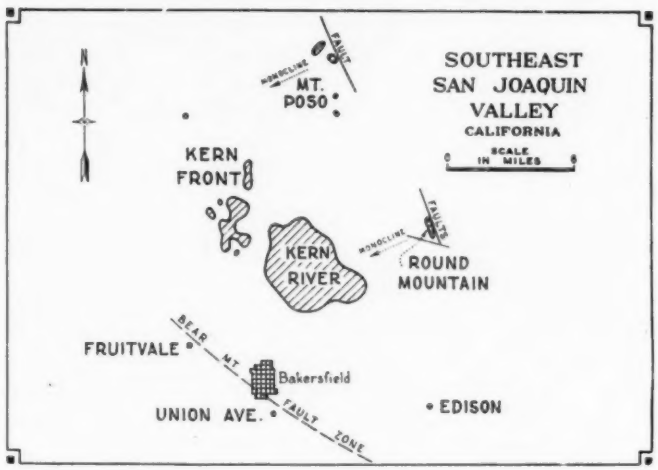

FIG. 4

MT. POSO AND ROUND MOUNTAIN

There are eleven wells in the Mt. Poso field, which was discovered in 1926. However, production is now only 100 barrels daily of 16° Bé. gravity oil, since many wells are shut in due to lack of transportation facilities. Initial yields have ranged from 250 to 750 barrels daily. What appears to be a 2½ mile extension to the field was made in December, 1927, making the total length of the field about 3½ miles. The Round Mountain field, a few miles east of the Kern River field, was discovered in May, 1927, 350 barrels daily of 16° gravity oil being obtained in the first well. Since that time, two other wells producing 75 barrels of 26° gravity and 600 barrels of 16° gravity oil have been completed.

In both the Round Mountain and Mt. Poso fields the general structure is monoclinal with dips toward the San Joaquin valley. The oil accumulations are due to faulted conditions (Fig. 4). Production in both fields is obtained from the Temblor formation of Middle Miocene age from depths of less than 2,300 feet. At Round Mountain, indications are that production occurs in a pie-shaped structural wedge, bounded on the northeast and south by faults. In the Mt. Poso area a fault extending in a general north-south direction is apparently the major structural feature. Oil accumulation is controlled by low-dipping beds closing on the west side of the fault.

UNION AVENUE, EDISON, AND FRUITVALE

Interest in the Union Avenue, Edison, and Fruitvale areas adjacent to Bakersfield, is now at high pitch. Due to lack of surface evidence, it was necessary to engage in very detailed geological study to locate the discovery wells. Much valuable information was obtained through a study of the soils, as well as airplane pictures, in an attempt to determine the location of the highs in these areas.

The Union Avenue well has never been officially completed, but tremendous gas pressure was encountered and oil, mud and water shot over the derrick. The depth of this well at the time of the blowout was about 4,460 feet, but it has since been deepened to over 5,600 feet in an attempt to find lower sands. A second well is now being drilled, due to unsuccessful efforts to complete the original as a producer. The discovery well near Edison had a rated initial production of 75 barrels daily of 16° gravity oil from a depth of 4,000 feet. However, water troubles developed which have not been overcome.

The Fruitvale field was not discovered until February, 1928. The discovery well had an initial flow of 225 barrels of 22.7° gravity oil from a depth of 3,849 feet, has been holding up well and definitely proves a field at Fruitvale. The well is now producing 185 barrels daily and a pipe line has been laid to the field. Much activity is looked for in this area.

BUTTONWILLOW

Considerable gas development has taken place in the Buttonwillow area which is located in the valley far from the west side fields. Several large gassers have been obtained by operators in this field which have produced as much as 20,000,000 cubic feet daily. Efforts are being made to determine the reserves in this gas field with a view to supplying natural gas to the San Francisco Bay and other central California districts. Acreage in the Buttonwillow field is closely held by numerous companies.

DISCUSSION

THERON WASSON: The author mentions airplane survey for discovery. Did airplanes help?

AUSTIN CADLE: My knowledge of the assistance rendered by airplanes in this area covers only the fact that airplane pictures of the topography of the flat-lying country were taken and used to assist in determining the location of geological "highs." For detailed information, it would be necessary to consult the geologists who did the work.

JAMIN ACTION—WHAT IT IS AND HOW IT AFFECTS PRODUCTION OF OIL AND GAS[1]

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ABSTRACT

Jamin action is a physical phenomenon due to alternating globules of liquid and bubbles of gas in channels of capillary dimensions. It is beautifully illustrated in the Jamin capillary tube. This tube is easily prepared by placing a vacuum in communication with one end of an ordinary capillary tube, and filling with globules and bubbles by means of a wet cloth applied with the finger at the other end of the tube.

When the globules are in equilibrium their menisci have equal radii of curvature. By applying a pressure at one end of the tube the globules become "distorted," in that their menisci assume unequal radii of curvature. In this condition they are able to offer a small resistance to the applied pressure. In doing this they retain some of the fluid within the tube, and prevent its escape from the open end.

A natural reservoir may be described as a huge bundle of capillary tubes radiating in all directions from the well. The globules and bubbles offer a resistance to any hydrostatic pressure tending to push the fluids toward the open well. If this hydrostatic pressure is of sufficient intensity, it overpowers the combined resistance of all globules located on the radiating lines, but if it is not of sufficient intensity, these globules and bubbles may be said to dictate the conditions of production from the well. These alternative conditions with respect to pressure and resistance determine volumetric and capillary controls, respectively. Particular emphasis is placed upon the effects of Jamin action with regard to the rate of production, volume produced from the well, and percentage of recovery from the sands by natural flow; also the features accompanying the use of pumps or gas-lifts are discussed. The forced drive is given a brief review, and the paper concludes with a description of the method of discriminating in the field between volumetric and capillary controls.

Back in the year 1858 two interesting experiments were being performed simultaneously. Jamin, in Paris, was contributing to science by his work on capillarity, while Drake, in Pennsylvania, was contributing to industry by drilling the first oil well. To-day, 70 years after, it is my purpose to draw these experiments together, and show that they were fundamentally related in spite of the different purposes held in the minds of the two men at that time.

Jamin was, in fact, investigating the ascent of sap in trees. How can sap reach heights obviously greater than the *head in feet* equivalent to the pressure of the atmosphere? During the course of this investigation Jamin made an interesting discovery concerning the behavior of globules of liquid and bubbles of gas in capillary tubes. The account of

[1]Read before the Association at the San Francisco meeting, March 22, 1928.

his discovery appears in the *Comptes Rendus* of the French Academy of Sciences, Volume 50, of the year 1860. He says:

> If a capillary tube be taken, of one meter length, more or less, and one of its ends be placed into communication with a vessel containing a vacuum, there will be a current of air passing through the tube from the atmosphere to the vessel. Then, if the finger with a wet cloth attached be placed at the free end of the tube, touching and held apart from such end alternately many times and at equal intervals, it will be noted that globules of water, separated by bubbles of air, will traverse the tube. . . The apparatus prepared in this manner possesses very peculiar properties.

I have repeated these experiments for the purpose of observing these very peculiar properties which he proceeds to describe in detail. Figure 1 (*a*) represents a piece of ordinary capillary tubing filled in the prescribed manner. The same tubing, when previously melted in a fish-tail Bunsen burner at its center, and drawn out at length, appears as in Figure 1 (*b*) after being filled. These two tubes do not differ in any way from the ones used by Jamin. What are the properties of these tubes? I will quote again:

> When a pressure is exerted on one end of the tube, the first globule advances considerably, but the following one moves less and the last globule remains immobile. If the pressure exerted is P, the movement transmitted to the globules affects a definite number of globules n; if such pressure is $2P$, the perceptible movement extends over a number $2n$. In general the effect of the pressure will be noted over a number proportional to such pressure. . . With a very fine capillary tube I have been able to exert a pressure of three atmospheres on one of its extremities, and maintain the same during 15 days without detecting the slightest change in the tube with its globules. Inversely, if a partial vacuum is applied at one end of the tube, the first air bubble expands considerably, the next one less, and so on, the last ones remaining in repose so long as the diminution of the pressure has not reached the limit proportional to the number of globules. For the purpose of the experiment a long tube containing a great number of globules and bubbles was attached to the upper end of a mercury column, and it was noted that the mercury maintained its level to the same absolute degree as though the upper extremity were maintained absolutely sealed.

Three hundred globules in the tube, Figure 1 (*a*), can maintain indefinitely 12 centimeters of mercury, while 60 in the tube, Figure 1 (*b*), can maintain indefinitely the entire mercury column. Each globule offers a resistance to the pressure that is greater at one end than at the other, and the intensity of this resistance increases considerably as the diameter of the capillary bore is made smaller.

Figure 1 (*c*) represents a tube made up of both (*a*) and (*b*). Short pieces of the latter, selected for their diameter, are inserted at regular

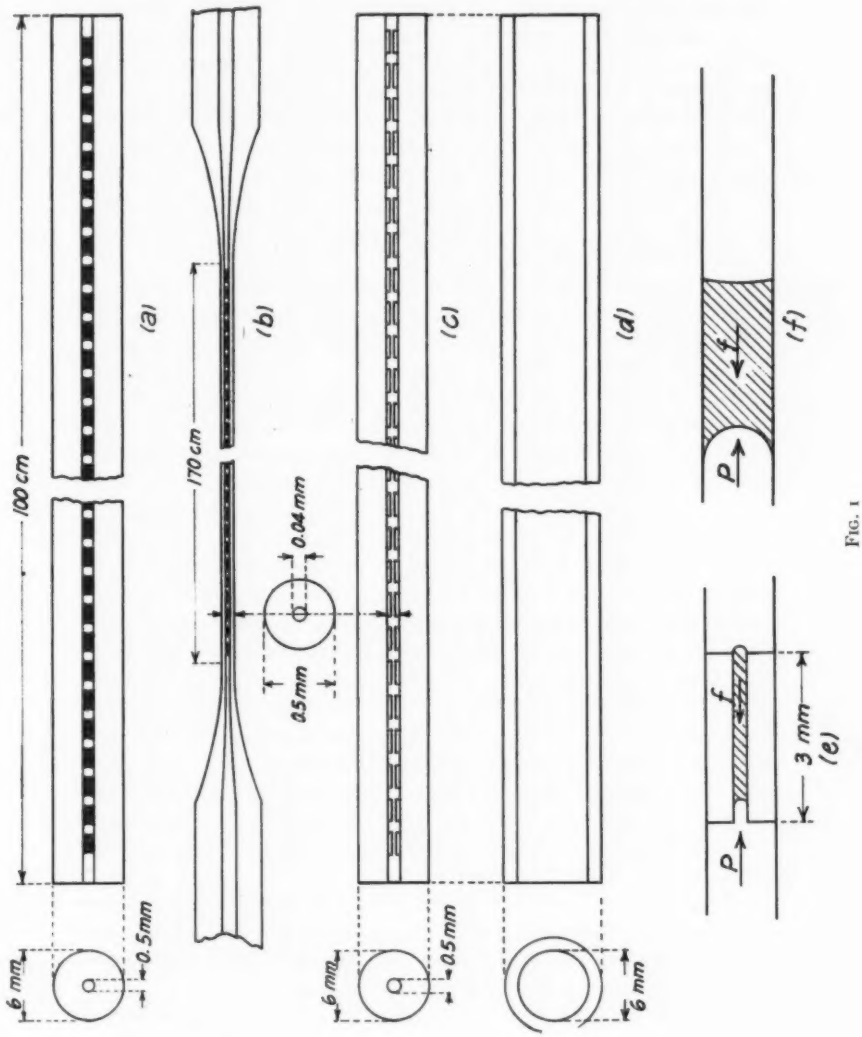

FIG. 1

intervals in the former. It is a simple matter to shrink these pieces into place, so that they will not shift their position. Now we have a tube with—as Jamin says—contractions and expansions. Where the globules can slide in the smooth bore, they must break and make in this one. The resistance offered by one globule is much greater under these conditions.

In Figure 1 (*d*) we have represented an ordinary piece of glass tubing which is easily filled with fine sand, globules, and bubbles. In place of this we might as well use a brass or steel tube of any convenient diameter and length. In all we find a resistance offered against any pressure or vacuum applied at one end.

In terms of mechanics this resistance is not difficult to explain. When the pressures on the two ends of a globule are of the same intensity, the radii of curvature of its menisci are equal. No resistance is offered by the globule. But when the pressures are not of the same intensity, the radii of curvature are not equal. The globule is distorted, and in this condition it opposes the greater pressure. The situation is shown in Figure 1 (*e*) and (*f*), where the pressure intensity at the left exceeds any pressure intensity at the right by an amount P, and where this P is opposed by a resistance of value f, a resistance presumably greater in Figure 1 (*e*) than in (*f*) in consideration of what has already been said.

Is it not clear, then, that we have a diminution of pressure as we proceed from the end where P is applied to the other end of the tube? In Figure 2 (*a*) we now see P applied at the left. The first globule offers a resistance f; consequently the bubble following this globule is supporting a pressure of intensity $P\text{-}f$. For the same reason the second bubble supports a pressure of intensity $P\text{-}2f$. In succession we find $P\text{-}3f$, $P\text{-}4f$, and so on, until at some position, depending upon the intensity of P and that of f, we find a bubble supporting a pressure $P\text{-}nf$ = zero. Certainly if we subtract enough f's from P we must have zero. Evidently P can be said to possess a radius of action R extending from the end for P to the position of the bubble that supports a pressure exactly equal to that at the end of the tube opposite to P.

It is important to remember that P is a pressure measured in excess of any amount of pressure exerted upon the neutral end of the tube. Here P is an amount greater than the pressure of the atmosphere, while the neutral end supports atmospheric pressure.

This diminution of pressure from a value P to zero in a distance R can be represented by the diagram of Figure 2 (*b*). Now this diagram is just as simple as it looks. At the left appears a vertical line properly

scaled for P. Why not erase P and place V there instead, and say that V represents the diminishing amount of fluid that is within the tube on applying P, and consequently that it also represents the diminishing amount of fluid to be produced from the tube when P is subsequently removed? I shall ask you to assume now that we have the right to do

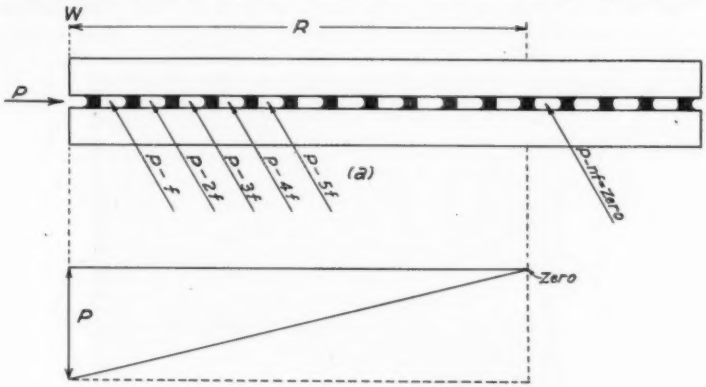

FIG. 2

this, instead of giving you the proof in terms of the mechanics of fluids. Indeed it is possible that you will not require a proof in view of the experience you have already had with fluids. At any rate, we here see that we deal with a triangle of fluid in filling and producing from these tubes.

A natural porous formation, containing both oil and gas, behaves as a bundle of these Jamin capillary tubes radiating in all directions from any well which penetrates it. The gas is liberated from solution upon the release of pressure, and it is this gas which forms the bubbles throughout the mass of oil in the formation. The situation is perfectly analogous to the one wherein the ordinary tube is filled at atmospheric pressure, and a vacuum is thereafter applied at one end now corresponding to the well at the end of natural tubes. The pressure is greater throughout the tubes than it is at the opening where production is permitted. P is simply a pressure exerted from the right in Figure 2 (*a*), instead of being exerted from the left in the manner shown. The globules are likewise reversed in their distorted positions. Along all radial lines from the well a triangle of fluid is removed from the formation, as shown in Figure 2 (*b*).

The triangle is merely a diagrammatical representation of the fluid produced from the formation. The actual position of the producible fluid before the well is drilled in is shown in Figure 3 (*a*). The shading is supposed to represent a perfect gradation from all oil immediately at the well to no oil at the distance *R* and beyond. If it were possible for us to press this quantity of oil to the roof of the formation, it would occupy the position shown in Figure 3 (*b*). Here we see,

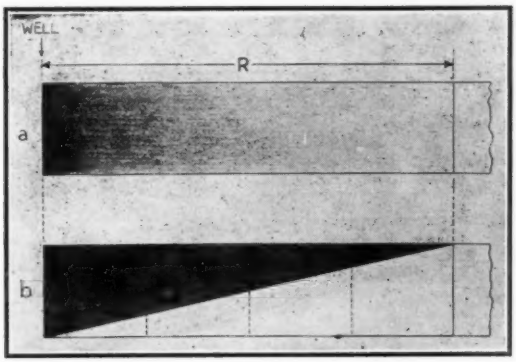

FIG. 3

then, the relation between the diagrammatic and actual lay of the prodicible fluid. In any case we do not need to specify particular vertical dimensions for the formation, for it may in fact be less than one foot or more than 500 feet. The triangle is nevertheless present throughout such a range.

If we accept the fact that there is a triangle to be found on all radii from the well, it is clear that the entire volume of fluid produced from the well occupies the space shown in Figure 4. This space is recognized as that of a cone whose volume is one-third that of the cylinder inclosing it. As a consequence we may say that the volume of oil produced from the well is one-third of all oil underlying the drainage area of the well. Two-thirds remains behind in the formation on account of the behavior of the globules and bubbles, a behavior which we shall conveniently call "Jamin action."

Corresponding to Figure 3 we have Figure 5 to represent the fluid so retained by Jamin action. The actual distribution of this fluid is shown in Figure 3 (*a*). If it were possible to press this quantity of fluid

to the floor of the formation, it would occupy the position shown in Figure 3 (*b*).

This is also clearly a triangle.

This problem is simple enough so long as we confine our attention to the single isolated well in the field. However, when wells are spaced so that their radii overlap, the situation becomes somewhat complicated.

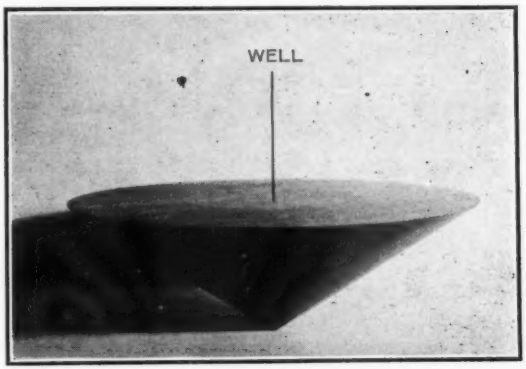

FIG. 4

In Figure 6 we have a well at *W* and a location at *L* at the distance *WS* apart. Their equal radii *R* overlap, and therefore their drainage areas interfere with each other. The cones are given a proper mathematical

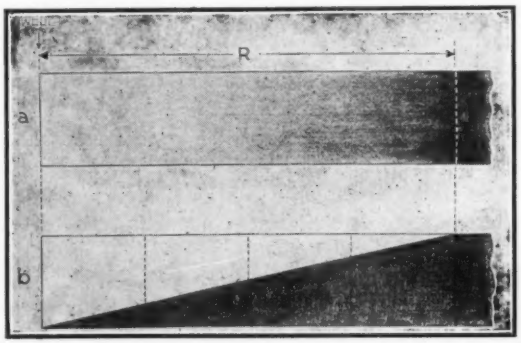

FIG. 5

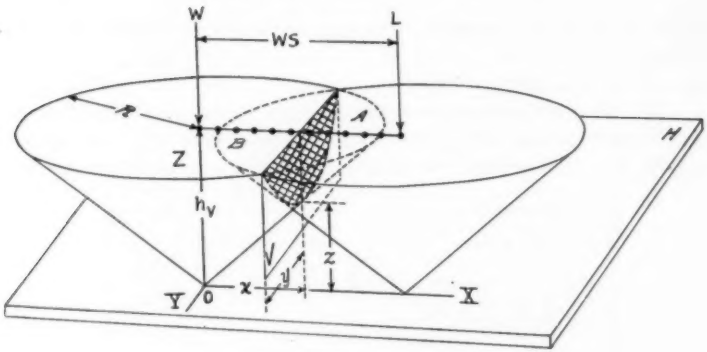

FIG. 6

setting for the purpose of determining matters which concern us each day in our oil and gas field practice. These are as follows.

1.—The effects of two closely adjoining wells upon each other as to their rates of production and the total volume to be produced separately from them. As a matter of fact we find that two wells in the position of *W* and *L* at any distance *WS* less than *2R* apart establish a neutral plane between them, the first well cutting off section *A*, the second section *B*, from the other. No oil or gas can pass this plane from *A* to *W*, and likewise no oil or gas can pass this plane from *B* to *L*. Both the rate and the volume are diminished by this interference, and the intensity of these effects is determinable in accordance with the degree of interference.

2.—The total production from a given field for a specified distance *WS* between wells. For any distance *WS* greater than zero some of the oil and gas must remain within the formation on account of Jamin action.

3.—The percentage recovery from the formation for a specified distance *WS* between wells. We have for several years attempted to estimate recovery from uncertain evidence, but we now have the means to make an accurate calculation. Total production from the field and percentage recovery are determinable in accordance with the degree of interference between the wells.

If any objection to our solutions to these problems may be offered on the grounds that ideal conditions are assumed in order to establish the principles, and that clearly no such ideal conditions were ever known to exist in actuality, our answer is simply that the principles are funda-

mental; they do not depend upon local conditions of heterogeneity in texture and structure; like the law of gravity, they are always in force. We can not get away from them.

We thus see what Jamin action is, and we can visualize perhaps some of its effects upon the production of oil and gas. Are we to believe that all natural reservoirs with porous formations must be subject to these principles whenever both oil and gas are present? Not at all. Some pools of oil and gas have a hydrostatic pressure bearing upon them. This pressure is due to the weight of a column of water standing in the formation in its reaches toward an outcrop at the surface. Where this pressure is of sufficient intensity to push the globules and bubbles toward the well regardless of the resistance which they offer, the well performs according to the usual laws of mechanics. The recovery of oil that is able to flow, that is, oil that is actually in the liquid state, is 100 per cent, provided each minor structure within the limits of the pool has at least one well at its crest. The drainage areas of all wells interfere with one another, but they do not establish neutral planes intervening. All wells have radii which extend throughout the area of the pool. Here a barrel of oil produced from one well means one barrel less for some other well or group of wells, a situation which we must see does not hold in case capillarity controls production.

I am saying that those natural reservoirs which possess wells producing according to the usual laws of mechanics are either under hydraulic or volumetric control, depending upon whether or not the hydrostatic pressure is maintained at a constant value during production. If the rate of entry of water at the outcrop is sufficient to offset the rate of production from the pool at depth, we have hydraulic control, but if the rate of production exceeds the rate of entry, we have volumetric control. Furthermore, I am saying that those natural reservoirs entirely subject to Jamin action are under capillary control. These names are adopted as a matter of convenience.

To return to capillary control once more, we find that the radius of action of the pressure P depends upon the intensity of P. If, at a given well, we may increase the effective value of P, say by decreasing the load against production, we may thereby increase R. This is actually done in the case of pumps and air or gas lifts. We produce at a more rapid rate, and we obtain more oil, by means of this sort of apparatus. Our cones are made larger; nevertheless we still have a cone in each case. The principles defining capillary control are in no way modified by pumps and lifts.

So long as we operate at single wells we are confined to circular areas surrounding the wells. But suppose we were to do what nature does not do for us; namely, install a pressure P at one well sufficiently intense to push all globules and bubbles to another well in spite of their resistance. What happens then? Our cones disappear; we operate upon cylinders; and our circular areas assume two centers. One center is defined by the well where we apply P, and the other is defined by the well where we withdraw the fluid. The forced drive, whether accomplished by water, air, or gas, is an operation confined to this area which is known in geometry as an ellipse. We change the control, but only within a restricted area. Capillary control continues to exist beyond the periphery of the ellipse; no oil beyond this periphery can be driven to the other well. If P should be made larger we increase the size of the ellipse, and this has a periphery similar to the smaller one.

Granted, then, that we agree to classify all natural reservoirs in accord with three controls. How are we to determine, in any particular field, the control with which we deal? For hydraulic control the determination is easy to make, for the pressure and the rate of production remain constant during production from the field. The distinction between the other controls, both of which provide for a decline in pressure and rate of production, is not difficult. We need only construct percentage curves for pressure and rate of production. If the rate curve overlies the pressure curve, as in Figure 7, we have volumetric control, whereas if the rate curve underlies the pressure curve, we have capillary control. The illustrated curves appear quite ideal. They need not be

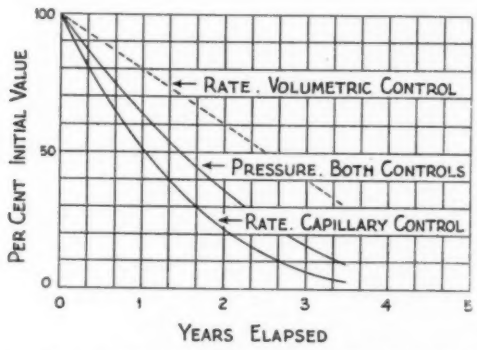

FIG. 7.—Rate-of-production curve underlyin , instead of overlying pressure curve.

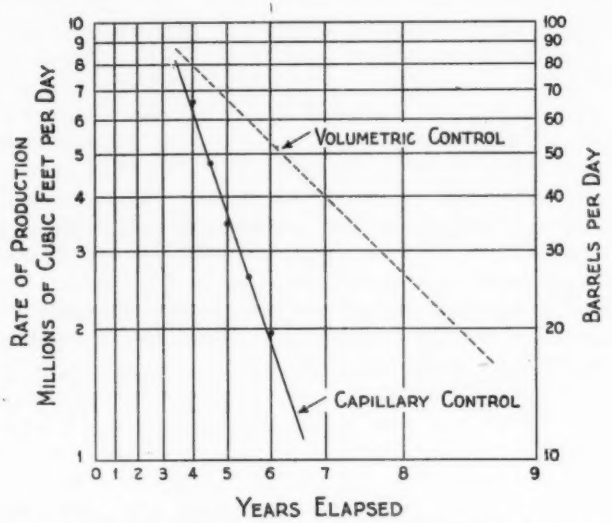

FIG. 8.—Rate-of-production curve with slope 3 to 1 compared with 1 to 1.

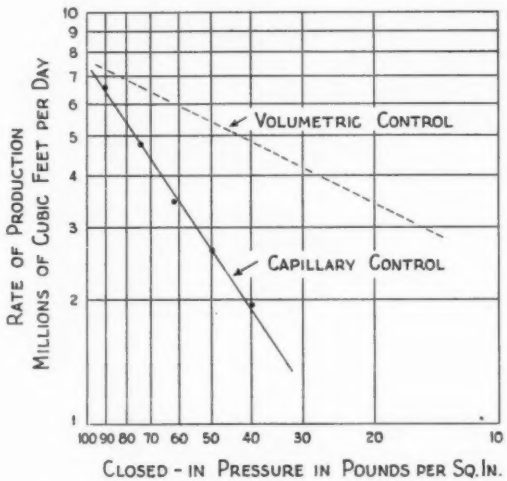

FIG. 9.—Rate-pressure curve with slope 3 to 2 compared with 1 to 2.

so in an actual determination, inasmuch as they always retain their respective positions on the plat, regardless of their irregularities. When we use logarithmic paper for plotting the rate-of-production curve, we have either a line with a slope of 1 to 1 for volumetric control, or one with a slope of 3 to 1 for capillary control, as shown in Figure 8. The data need not be exceedingly accurate for us to be able to make the distinction between these lines. Where we have the pressure and rate of production plotted on logarithmic paper, we find a line with a slope of 1 to 2 for volumetric control, and one with a slope of 3 to 2 for capillary control, as shown in Figure 9.

It is quite probable that many of you are already familiar with the curves as shown on these three plates. If this is true you may know at once the control of your fields.

GEOLOGICAL NOTES

NOTES ON THE MIOCENE OF ECUADOR

Tertiary sediments of Miocene age occur throughout an extensive pampa region west of Guayaquil and may be correlated with the formations in the vicinity of Zorritos, in Peru.[1]

These extensive Miocene deposits occur near the western margin of the Gulf of Guayaquil, and although the exact limits on the west and north have not been defined, outcrops have been observed almost as far north as Colonche. In the Santa Elena region proper the Miocene has not been recognized, nor is it probable that these deposits covered the older Tertiary as a distinct Miocene shore line has been observed farther east.

The Miocene age of the deposits here described was no doubt originally determined in 1922, by the geologists of the Standard Oil Company of California, which company later drilled a well near San Jose de Amen to a depth of more than 6,000 feet. Later investigations by the writer were corroborated by the valuable paleontological researches of A. A. Olsson who identified the following fossils:[2]

Mactra (*Matriculina*) sp.
Spisula sp.
Dosinia acetabulum Conrad
Callocardia cf. *gatunensis* Dall
Diplodenta sp.
Phacoides (*Lucinisca*) sp.
Tellina (*Eurytellina*) *aequicincta* Spieker
Cardium (*Trachycardium*) *peruvianum* Spieker
Crassatellites nelsoni Gryz.
Arca (*Scapharca*) 3 sp.
Turritella altilira Conrad
Bivonia sp.
Calyptraea sp.
Crucibulum cf. *costatum*

[1]T. O. Bosworth, *The Geology and Paleontology of Northwest Peru*, 1922. J. Grzybowski, "Die Tertiarablagerungen des nordlichen Peru," *Neues Jahrb. für Min.* etc. Beil. Band XII (1899). E. W. Berry, "Miocene Plants of Peru," *Proc. U. S. Nat. Mus.* LV (1919).

[2]Personal communication, published by courtesy of O. B. Hopkins, International Petroleum Company, Toronto, Canada.

Pyrula peruviana Spieker
Terebra Wolfgangi
Conus bocapanensis Spieker
Turris albida Berry
Drillia venusta Sowerby
Drillia cf. *consors* Sowerby
Polinices 2 sp.
Phos. cf. *beteyensis* Olsson

Excellent sections in the Miocene are found along the railroad cuttings from San Jose de Amen to Playas, and farther west these exposures occur almost as far as Zapotal. The topography of this Miocene tract presents little of interest, and consists essentially of rolling pampa covered largely by vegetation of a sub-tropical type. On the east, toward the broad estuary of the Guayas, the Miocene strata are probably obscured by recent alluvium or similar detritus, and their western extension appears to be limited by conspicuous hill ranges which probably existed as topographical units before the sedimentation of the Miocene began.

In certain localities, notably in the vicinity of Playas, the Miocene deposits rest unconformably on the tilted and denuded beds of the older Tertiary, the latter dipping at a high angle. It is apparent, therefore, that following the close of Oligocene time the Tertiary deposits suffered considerable deformation as a result of the prevailing tectonic forces and, as a final result, the terrain became uplifted into a land mass. A long period of denudation and consequent erosion then followed, and even at the present time many of the more outstanding features in the topography found in this part of the country probably date from this period. The latter phase of tectonic stability was temporary and was succeeded by gradual subsidence of the older Tertiary terrain. This made possible the incursion of the Miocene ocean which probably originated from the south, thus causing regional sedimentation (probably in the form of an overlap) over a large expanse of both Oligocene and Eocene formations.

As previously mentioned, no undoubted Miocene rocks have been found *in situ* in the Santa Elena region. It is quite possible, therefore, that this part of the continent formed a land mass during Miocene time. It has been estimated that at least 5,000 feet of Miocene deposits are represented in Ecuador; also, the Miocene embayment was very extensive, and the sediments were deposited more or less contemporaneously with the regional subsidence of the basin.

Miocene formations have been found as far as the Cerros de Saya and Zapotal. They also underlie the greater part of the present Gulf of

Guayaquil, and have been recognized along the valley of Rio Daule. To the writer's knowledge no Miocene rocks have been recorded north of Colonche, nor do they occur along the coast on the north as far as Manta. East of the Cordillera de Colonche, however, a large basic igneous mass is found penetrating the fossiliferous Miocene formations, having caused the latter to be metamorphosed into a coarse marble.

LITHOLOGICAL FEATURES

The Miocene formations found in the region under discussion consist of loosely consolidated sandstones and clays with a few harder beds of fine-grained sandstone characterized by small rounded pebbles of quartzite. Certain horizons are very fossiliferous, and in these the formation itself is hard and calcareous,—a typical calcareous grit. Most of the strata are also ferruginous and some of the argillaceous members are distinctly saline. Near San Jose de Amen a white, marly limestone occurs, which is, however, probably a lenticular form. A marked feature of the whole facies, however, is the comparative incoherency of the stratification and the presence of incipient concretionary structures. Certain calcareous and fossiliferous zones, however, simulate concrerionary masses, this condition probably being caused by the separation of an excess of lime carbonate.

GEORGE SHEPPARD

ANGLO-ECUADORIAN OILFIELDS, LTD.
SANTA ELENA, ECUADOR

DISCUSSION

OCCURRENCE OF FOLDS OF THE OSAGE TYPE

Resumé.—Folds similar to those of Osage County, Oklahoma, are fairly extensively developed and are believed to have had the same origin.

The essential characteristics of the folds of Osage County when considered as a type are (1) low dip and (2) nearly equal dimensions in all horizontal directions.[1] Other characteristics must be consistent with an origin by compressive forces generated locally and acting more or less equally in all directions. Such folds are not readily detected and future detailed mapping (of areas not so mapped) may reveal their existence in many places where at present they are not suspected. However, their presence is recorded by publications of the United States Geological Survey in Pennsylvania,[2] Ohio,[3] Illinois,[4] Kentucky,[5]

[1]Computed from estimates by Chamberlin and Salisbury. See *Geology*, Vol. 1, p. 551.

[2]L. H. Woolsey, Beaver quadrangle, Pennsylvania, *Folio 134;* M. J. Munn, Sewickly quadrangle, Pennsylvania, *Folio 176;* E. W. Shaw and M. J. Munn, Burgettstown and Carnegie quadrangles, Pennsylvania, *Folio 177;* E. W. Shaw, E. F. Lines, and M. J. Munn, Foxburg and Clarion quadrangles, Pennsylvania, *Folio 178;* W. T. Griswold and M. J. Munn, "Geology of Oil and Gas Fields in Steubenville, Burgettstown, and Claysville Quadrangles, Ohio, West Virginia, and Pennsylvania," *Bull. 318.*

[3]D. D. Condit, "Oil and Gas in the Northern Part of the Cadiz Quadrangle, Ohio," *Bull. 541*, Pt. II-a, pp. 9-17; W. T. Griswold, "Structure of the Berea Oil Sand in the Flushing Quadrangle, Harrison, Belmont, and Guernsey Counties, Ohio," *Bull. 346;* D. D. Condit, "Structure of the Berea Oil Sand in the Summerfield Quadrangle, Guernsey, Noble, and Monroe Counties, Ohio," *Bull. 621-n*, pp. 217-31.

[4]E. W. Shaw and T. E. Savage, Murphysboro and Herrin quadrangles, Illinois, *Folio 185;* Henry Hinds, Colchester and Macomb quadrangles, Illinois, *Folio 208;* E. W. Shaw and A. C. Trowbridge, Galena and Elizabeth quadrangles, Illinois and Iowa, *Folio 208;* E. W. Shaw, Carlyle and Centralia quadrangles, Illinois, *Folio 216;* F. W. DeWolf, "Coal Investigations in the Saline-Gallatin Field, Illinois, and the Adjoining Area," *Bull. 316*, Pt. II-b, pp. 116-36.

[5]W. C. Phalen, Kenova quadrangle, Kentucky, West Virginia, and Ohio, *Folio 184;* E. W. Shaw, "The Irvine Oil Field, Estill County, Kentucky," *Bull. 661-d*, pp. 141-92; E. W. Shaw and K. F. Mather, "The Oil Fields of Allen County, Kentucky, with Notes on the Oil Geology of Adjoining Counties," *Bull. 688.*

Missouri,[1] probably in Indiana,[2] Kansas,[3] Texas,[4] and Oklahoma,[5] and possibly in Colorado[6] and Montana.[7]

As indicated by the accompanying table, the folds of Osage County, of western Pennsylvania and eastern Ohio, and of central Illinois have the following characteristics in common: small size, nearly equal horizontal dimensions, slight dip, slight deformation, similarity in form between domes and basins, and greater number or larger size of domes as compared with basins. In all three areas the domes and basins are associated with terraces and inverted terraces, the folds being independent forms rather than parts of larger structures. These characteristics, as has previously been stated, either indicate an origin by compressive forces acting more or less equally in all horizontal directions or, at least, are consistent with such an origin.

The probable absence of horizontal shearing movement in the Ohio-Pennsylvania and Illinois areas explains why the folds of these areas are not so elongate or so definitely oriented as those in Osage County.

The Ohio-Pennsylvania and Illinois areas furnish no data concerning the relation of surface folds to irregularities in the topography of an underlying granitic mass, as the granite rocks, if present, exist at unknown depths.

The occurrence of these folds is consistent with the principles governing their distribution;[8] they are all found in the interior of the continent and, with the exception of those in western Pennsylvania, are not found in the same area as the elongate type of folds, and even here, they may have been formed at different times. In western Pennsylvania intermediate types are lacking; the structures are either more than ten or less than three times as long as wide, implying distinct dynamics for the two types. The continuation of the domes of the Osage type east of the western limit of the Appalachian folds, without any change in their characteristics, suggests that they once continued much farther to the east and were subsequently obscured by the development of the Appalachian folds. The irregular and branched axes of the anticlines and

[1]Henry Hinds and T. C. Greene, Leavenworth and Smithville quadrangles, Missouri and Kansas, *Folio 206*.

[2]M. L. Fuller and G. H. Ashley, Ditney quadrangle, Indiana, *Folio 84*.

[3]F. C. Schrader, Independence quadrangle, Kansas, *Folio 159*.

[4]E. W. Shaw, G. C. Matson, and C. H. Wegemann, "Natural Gas Resources of Parts of North Texas—Gas in the Area North and West of Fort Worth, Gas Prospects South and Southeast of Dallas—with Notes on the Gas Fields of Central and Southern Oklahoma," *Bull. 629;* C. S. Ross, "The Lacasa Area, Ranger District, North-Central Texas," *Bull. 726*, Pt. II-g, pp. 303-14.

[5]A. E. Fath, "Structure of the Northern Part of the Bristow Quadrangle, Creek County, Oklahoma, with Reference to Petroleum and Natural Gas," *Bull. 661*, Pt. II-b, pp. 69-99; C. H. Wegemann and K. C. Heald, "The Healdton Oil Field, Carter County, Oklahoma," *Bull. 621*, Pt. II-b, pp. 13-30; C. D. Smith, "The Glenn Oil and Gas Pool and Vicinity, Oklahoma," *Bull. 541*, Pt. II-b, pp. 34-48.

[6]G. W. Stose, Apishapa quadrangle, Colorado, *Folio 186*.

[7]Eugene Stebinger, "The Sidney Lignite Field, Dawson County, Montana," *Bull. 471*, Pt. II-d, pp. 284-318.

[8]Robert Wesley Brown, "Origin of Folds of Osage County, Oklahoma," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 12, No. 5, pp. 501-13.

TABLE SHOWING CHARACTERISTICS OF DOMES AND BASINS IN ILLINOIS, OHIO, PENNSYLVANIA AND OSAGE COUNTY

	Western Pennsylvania and Eastern Ohio	*Central Illinois*	*Twenty Townships in Osage County, Oklahoma*
Approximate number of square miles in area	1600	1400	7200
Approximate per cent of area within closed contours	2	4	12
Domes			
Number	22	8	151
Average width in miles	0.8	1.6	0.53
Average length in miles	1.4	2.5	0.95
Ratio of length to width	1.75	1.5	1.82
Average height in feet	14	32	17.8
Relative shortening—*			
along short axis	21×10^{-6}	29×10^{-6}	85×10^{-6}
along long axis	7×10^{-6}	11×10^{-6}	25×10^{-6}
Basins			
Number	7	10	89
Average width in miles	0.8	1.5	0.42
Average length in miles	1.2	2.5	0.72
Ratio of length to width	1.5	1.67	1.72
Average height in feet	9	14	12.4
Relative shortening—*			
along short axis	9×10^{-6}	6×10^{-6}	63×10^{-6}
along long axis	4×10^{-6}	3×10^{-6}	21×10^{-6}

*By relative shortening is meant the amount a given unit is shortened when measured in terms of the given unit. If a mile has been shortened 4 inches, it has been shortened .000063 miles, and .000063 or 63×10^{-6} is the amount of the relative shortening.

synclines of the Sewickly quadrangle are such as might reasonably be expected to develop in the initial stages of an invasion of anticlinal deformation into an area where irregularly distributed domes and basins had previously existed.

Folds of the Osage type occur in numerous places and in certain areas are rather extensively developed—facts of great economic significance, as these folds, where other conditions are favorable, may form traps for the accumulation of oil.

ROBERT WESLEY BROWN

CORRECTION

On page 530, Vol. 12, No. 5 (May, 1928) of this *Bulletin*, in the first seven lines on the page, an unfortunate mistake was made in the printing. The Sun Oil Company, in its work in East Texas, had only one seismograph party with one instrument which was used in one small area for about three weeks. It carried on no exploration for other companies.[1]

F. H. LAHEE

DALLAS, TEXAS
May 17, 1928

[1]The editor regrets that this error escaped his attention. J.P.D.H.

REVIEWS AND NEW PUBLICATIONS

"Fifty Years of Petroleum Geology. By D. W. OHERN. *The Johns Hopkins University Studies in Geology*, No. 8, pp. 83-120. Baltimore, The Johns Hopkins Press, 1927. Price, $1.50.

This is one of several papers presented at the geological conference during the fiftieth anniversary of The Johns Hopkins University in October, 1926, and published as a bulletin in the University's series of Studies in Geology. The other papers in the bulletin are: "Contributions of Hopkins to Geology," by W. S. Bayley; "Geology at Work," by George Otis Smith; "Fifty Years of Progress in Petrography and Petrology," by Florence Bascom; "Progress in Ore Genesis Studies," by Benjamin LeRoy Miller; and "Progress in Structural Geology," by Edward B. Mathews.

Ohern treats his subject under several headings, in the main following its development from a historic point of view. He comments on the lack of much other study after the first presentation of the anticlinal theory by Winchell, Newberry, and White in the early seventies, until I. C. White published, in 1885, the results of his work of the previous two years, definitely establishing the anticlinal theory and marking an epoch in oil and gas geology. Except for modifications by Minsell and by Orton to explain conditions in producing areas in West Virginia and Ohio respectively, there was another long period in which little appeared in the literature of oil and gas, until the finding of oil at Spindletop in 1901 stimulated geologic study. Woolsey's observations that the lenticular shape of sand beds is important as governing both their presence and productivity is considered by Ohern to be a contribution of exceptional value.

As to migration of oil, the author believes that Munn's observation that "Fresh water in beds relatively close to points of outcrop shows a steady change to salt when traced down the dip," is of great importance; and he favors Munn's theory of hydromotive force, rather than that of migration by buoyancy. The inorganic versus the organic origin of oil and gas is discussed briefly, with resumé of the main experimental work done, and statement that

> Finally in these days of close detailed work in oil and gas fields the geologist finds little or no geologic evidence supporting the inorganic theory. In fact, the geographic distribution and the geologic relations of oil and gas point too strongly in another direction, and the theory has been abandoned by practically all geologists except Coste.

Although throughout the past fifty years the powers of observation of the geologist have not appreciably increased, field methods have greatly improved. The planetable method of survey has replaced that of the clinometer-compass, and microscopic work has in recent years developed rapidly, for the correlation of beds and of well samples through their lithology and micro-fauna. Even more rapid has been the development of geophysical instruments for the

study of subsurface conditions. After citing the success of the seismograph and torsion balance in locating salt domes, he says:

> If the writer is correctly informed, the seismograph has not yet been successfully used in determining the warping of subsurface strata. Whether this method will eventually reach such degree of refinement as to make such determination possible remains to be seen.
>
> The same is true of the torsion balance. So far as the writer is aware, it is being used successfully in the determination of concealed salt domes and buried granite ridges but has not been successfully applied to the determination of warping of subsurface strata.
>
> The writer is of the opinion that these geophysical methods represent the greatest advance that has been made in geologic field methods for decades. It is too early to depict what the outcome of such methods may be but it is safe to predict that geophysical methods in general have had only a beginning in geology and it is probably true also that few, even of the geologists, appreciate the importance of this new departure and the probable effect on the future of the science.

Writing in 1926, Ohern does not mention the magnetometer and allied instruments, registering deviations in magnetic and electric intensity, which are now coming into experimental use.

As by-products of petroleum geology, the author calls attention to discoveries made by study of well logs, such as the buried granite ridge of Kansas and that of the Texas Panhandle, of "shoestring sands" and of major unconformities and faults of which there is no surface evidence.

The studies on the origin of salt domes and the major conclusions concerning them, he also regards as "to no inconsiderable extent a by-product of petroleum geology."

In writing of the carbon-ratio theory advanced by David White, the author considers it to be one of the most important contributions that has been made to petroleum geology; especially since it has been given economic application by many geologists who are deterred by it from recommending exploitation for oil in areas having coals of high percentages of fixed carbon, or in areas of intense folding.

The possible economic value of observing temperature gradients in wells is mentioned, as a new phase in the study of petroleum geology.

The paper as a whole constitutes a clear and concise summary of the past development of the science in its main technical aspects. Something might also have been said of the increasingly rapid advances during the past few years due to closer coöperation of workers, brought into touch through local and national associations; and of the active stimulus for research work in the various phases of the subject. This is especially true of applied geophysics, in which Ohern was one of the pioneers in 1921; of studies on the origin of oil, started by David White in 1924; and of various other research studies now going on under the direction of the National Research Council.

G. A. WARING

TULSA, OKLAHOMA
April, 1928

"Oil Sands and Production Relations," by H. C. GEORGE and W. F. CLOUD. *Oklahoma Geological Survey Bulletin 43*. Norman, Oklahoma, August, 1927. 142 pp., 19 figs. Price, $1.00.

In the words of the authors "the purpose of the report is to present to the general public and especially to the average oil man engaged in the drilling and production branches of the petroleum industry, a brief outline and selected bibliography of the generally accepted opinions of geologists, drillers, petroleum engineers, and production superintendents regarding oil sands and production relations."

The report "deals with types of oil reservoir rocks or oil sands; structural features favorable for oil and gas accumulation; the physical character of oil sands; sub-surface information secured during drilling which will later be of great value to the oil producer; factors which affect oil recovery, depending upon the type of oil sand and the character of the oil produced; methods for oil well rejuvenation; effectiveness of oil recovery methods; and the probable trend of future production methods." The bulletin does not go into the various types of oil-well equipment or the details of various production methods.

The authors of this bulletin have combined in one report a summary outline of 127 selected articles which have to do with the oil sand or the oil reservoir rock and production relations. They have also contributed freely from their own ideas, observations and experiments. The bulletin brings together the scattered information on oil sands and production relations, which heretofore no one has attempted to do in a separate volume. The report is briefly written and summary quotations are given from several of the original articles.

The bulletin is well written for the purpose intended. Those who wish to read further are given a good reference list of the original articles.

Though a thorough study of oil sands and production relations has been much neglected in the past by production departments of oil companies in planning production operations, the subject is now being given considerable attention by these departments and will be given still more in the future. This bulletin is a timely publication.

A. F. MELCHER

TULSA, OKLAHOMA
April 25, 1928

RECENT PUBLICATIONS

GENERAL

Analytical Principles of the Production of Oil, Gas, and Water from Wells, by Stanley C. Herold. Stanford University Press, Stanford University, California. Ready in October, 1928. Price, $7.50, postpaid.

American Men of Science. Edited by J. McKeen Cattell and Jaques Cattell. Fourth edition, December, 1927. Biographical directory. viii + 1,132 pp. The Science Press, Grand Central Terminal, New York, N. Y. Price, $10.00, postpaid.

Congrès Géologique International, Comptes Rendus de la XIV^e Session, en Espagne, 1926. Second issue of the proceedings of the Fourteenth International Geological Congress, Madrid, Spain. Contains 12 papers grouped under Subject II, "Mediterranean Geology," and 7 papers under Subject III, "Cam-

brian and Silurian Fauna." In French, Spanish, German, and English. Issued by Instituto Géologico y Minero de España, Cristobal Bordiu, 12, Madrid, Spain, 1927. Pp. 333-773, well illustrated.

"Map Compilation from Aerial Photographs," by T. P. Pendleton. *U. S. Geological Survey Bulletin 788-F.* Washington, D. C. iii + 41 pp., 12 illus. Free.

"Plants as Indicators of Ground Water," by O. E. Meinzer. *U. S. Geological Survey Water-Supply Paper 577.* Washington, D. C. v + 95 pp., 27 illus. Free.

COLORADO

"Geology and Oil and Gas Prospects of Northeastern Colorado," by K. F. Mather, James Gilluly, and R. B. Lusk. *U. S. Geological Survey Bulletin 796-B.* Washington, D. C. iv + 60 pp., 10 illus. Free.

OKLAHOMA

The following publications have been issued by the Oklahoma Geological Survey, Norman, Oklahoma:

"Oil and Gas Geology of Rogers County," by E. G. Woodruff and C. L. Cooper. *Bulletin 40-U.* 24 pp., 5 illus. Price $0.30.

"Oil and Gas Geology of Seminole County," by A. I. Levorsen. *Bulletin 40-BB.* Price, $0.30.

THE ASSOCIATION LIBRARY

Headquarters acknowledges accessions:

GENERAL

From W. L. Russell:

"The Origin of Artesian Pressure"

MEXICO

From W. Storrs Cole:

"A Foraminiferal Fauna from the Chapapote Formation in Mexico"

TECHNICAL PERIODICALS

In addition to the lists published in the November and December, 1927, issues of the *Bulletin*, the following exchange periodicals are regularly received at headquarters:

Boletin de la Sociedad Geológica del Perú (Lima)
California Oil World (Los Angeles)
Geographical Review (New York)
Inland Oil Index (Casper, Wyoming)
Leidsche Geologische Mededeelingen (Leyden)
Proceedings of the U. S. National Museum (Geology) (Washington, D. C.)
Science (Lancaster, Pennsylvania)
Science News Letter (Baltimore)

THE ASSOCIATION ROUND TABLE

MEMBERSHIP APPLICATIONS APPROVED FOR PUBLICATION

The Executive Committee has approved for publication the names of the following applicants for membership in the Association. This does not constitute an election, but places the names before the membership at large. In case any member has information bearing on the qualifications of these applicants, please send it promptly to J. P. D. Hull, Business Manager, Box 1852, Tulsa, Oklahoma. (Names of sponsors are placed beneath the name of each applicant.)

FOR ACTIVE MEMBERSHIP

Hans Ervin Althaus, Comodoeo Rivadavia, Argentine, S. A.
D. Trumpy, L. F. Nuttall, J. B. Orynski

Lewis Alexander Bond, Pasadena, Calif.
E. F. Davis, Roy R. Morse, M. G. Edwards

Josiah Bridge, Rolla, Mo.
Anthony Folger, Raymond C. Moore, Charles N. Gould

George Whitfield Halse, Maracaibo, Venezuela, S. A.
Launcelot Owen, Ralph Richards, Floyd Hodson

Arthur L. Hawkins, Tulsa, Okla.
Ray V. Hennen, R. J. Metcalf, Arthur M. Hagan

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Memorial

FRANK MORSE SMITH

Frank Morse Smith died on April 1, 1928, as a result of an automobile accident near Rawlpindi, Punjab, India. He had recently arrived in that country as consulting petroleum engineer for the Attock Oil Company, Ltd., of London. The accident occurred while driving to the oil fields with three other company officials, when the car skidded and overturned, killing one man instantly and fatally injuring Smith, who died about 12 hours later.

Frank Smith was born May 5, 1889, in Floriston, California. He graduated from the University of California in the year 1914, having majored in mining engineering. He followed mining until the year 1917, at which time he enlisted in the Signal Corps of the United States Army, for which branch of the service he was admirably suited because of his training in telegraphy during boyhood. During the World War he served in France and was for a time in charge of communications in Paris, with rank of first lieutenant. After the signing of the armistice he attended the University of Birmingham, England, where he met Elsie McIntosh who became his wife in 1922.

After the war he returned to California and entered the employ of the State Mining Bureau, Department of Petroleum and Gas, and was stationed at Taft, California, as inspector and later as petroleum engineer. During this connection he gained a wide experience and acquaintanceship with the California oil industry.

In the latter part of 1921 he resigned to join the geological staff of Union Oil Company of California, and later took charge of operations for an oil company in Arkansas.

On his return to California he entered the employ of Pan-American Petroleum Company and held a leading position with its geological department for three years.

During the last three years of his life he was consultant in geology, engineering, and management for various oil operators, one of his noteworthy achievements being the successful handling of a trusteeship in bankruptcy for an oil company in Kern County, California, which through his skill and integrity paid a large return to its shareholders.

Frank Smith was a man of sterling and lovable qualities, and of unusual size, both mentally and physically. He enjoyed the highest regard as a petroleum engineer and geologist, and the oil industry has lost by his untimely death a man who would have been one of its leaders.

R. M. BARNES

LOS ANGELES, CALIFORNIA
May 1, 1928

AT HOME AND ABROAD

Mr. and Mrs. ULRICH R. LAVES announce the birth of a son, Robert Sears Laves, on March 21, 1928. Mr. Laves is with the Roxana Petroleum Corporation at El Reno, Oklahoma, where he recently moved from Clinton.

The Kansas Geological Society is planning its second annual field conference for August 26 to September 2, inclusive. The party is to start from Springfield, Missouri. The starting point in Arkansas is Harrison. Further information may be obtained from L. W. Kesler, president, 1007 Union National Bank Building, Wichita, Kansas.

R. E. REYNOLDS, recently geologist with The Texas Company in west-central Texas, may be addressed at 1311 Amarillo Street, Abilene, Texas.

STANLEY C. HEROLD, of Stanford University, California, is the author of *Analytical Principles of the Production of Oil, Gas, and Water from Wells*, a new book coming from the Stanford Press in October.

R. S. MCFARLAND, president of the A. A. P. G. and secretary of The Twin State Oil Company, Tulsa, Oklahoma, addressed the Mid-Continent Oil Scouts' and Landmen's Association at their annual banquet at Guthrie, Oklahoma, April 27. His subject was "Coöperation in the Scouting, Land, and Geological Departments." A. F. MELCHER, consulting geologist, 1137 North Cheyenne Avenue, Tulsa, presented a paper on "Problems of Re-Pressuring in Oil Sands" at the business meeting, April 28.

ROY A. REYNOLDS announces the opening of offices for the general practice of consulting petroleum geology. Associated with him are NOYES B. LIVINGSTON and O. W. REYNOLDS at 2014 Fort Worth National Bank Building, Fort Worth, Texas.

L. P. TEAS, for several years geologist for the Humble Oil & Refining Company at the Shreveport, Louisiana, office, is now at the headquarters of the company in Houston, Texas.

J. E. ELLIOTT, first vice-president of the A. A. P. G. and president of the Elliott Core Drilling Company of Los Angeles, California, was in Tulsa, Oklahoma, to attend the meeting of the executive committee of the Association held on June 4.

GEORGE A. WEAVER, recently division geologist of the Pure Oil Company at Fort Worth, Texas, has been transferred to the Associated Orinoco Oil Company, the Venezuela operating company of the Pure.

LOUIS H. FREEDMAN is with the Snowden-McSweeney Oil Company at Fort Worth, Texas.

JOHN M. LOVEJOY, vice-president and general manager of the Amerada Petroleum Corporation of Tulsa, Oklahoma, is a member of the advisory com-

mittee of seven selected from Oklahoma and Kansas operators for coöperative efforts to restrict production. Other members of the committee are E. B. REESER, E. H. MOORE, J. T. KING, DANA H. KELSEY, WIRT FRANKLIN, and RUSH GREENSLADE.

The International Petroleum Exposition for 1928 will be held at the exposition grounds at Tulsa, Oklahoma, October 20 to 29, inclusive.

ARTHUR KNAPP, petroleum economist and gas engineer, Box 1902, Philadelphia, Pennsylvania, has published another pungent parable with a moral. The *Oil Weekly* carries it on page 30 of the issue of April 27. It is entitled "The Cat and the Mice."

FRANK C. GREENE, chief geologist for the Skelly Oil Company at Tulsa, Oklahoma, gave a paper on "Well-Log Correlation in Eastern Oklahoma" before the Tulsa Geological Society, April 16.

CHARLES N. GOULD, director of the State Geological Survey of Oklahoma, addressed the North Texas Geological Society at their operators' dinner at Wichita Falls, April 28, on the subject, "Early History of Mid-Continent Geology."

EDWARD BLOESCH, consulting geologist, 440 Kennedy Building, Tulsa, Oklahoma, is in Switzerland this summer.

G. C. GESTER, past-president of the A. A. P. G. and chief geologist of the Standard Oil Company of California, made a trip to Texas in May.

ROSWELL H. JOHNSON, professor of oil and gas production at the University of Pittsburgh, Pennsylvania, and PAUL RUEDEMANN, geologist of Tulsa, Oklahoma, are authors of a new book, *Appraisal of Oil and Gas Properties.*

E. G. ALLEN, central division general superintendent of the Roxana Petroleum Corporation, Fort Worth, and JOHN R. SUMAN, director of the Humble Oil and Refining Company, Houston, are members of the advisory committee recently named by oil operators to represent them in working with the railroad commission in prorating Winkler County, Texas, production. The other members of the committee are J. H. REYNOLDS, of Cisco; P. W. WOODRUFF, of Shreveport; B. S. SORELLE, of Fort Worth, and E. A. LANDRETH, of Fort Worth.

W. ELMER EKBLAW has been promoted from associate to full professor of agricultural geography at Clark University.

ALBERT O. HAYES, for the past two years visiting professor of geology, has been appointed full professor and head of the department of geology at Rutgers University.

WALT M. SMALL returned to his home in Cooperstown, Venango County, Pennsylvania, last month, after visiting in Houston, San Angelo, and Tulsa. Mr. Small recently completed a season's work in the Permian basin of western Texas, a two months' trip on professional work in the California fields, and a business trip of six weeks in Mexico.

LEWIS B. KELLUM, recently stationed at Eagle Pass, Texas, moved to Mexico in April. His address is Apartado 675, Tampico, Tamps.

RUSSELL S. TARR has moved his office from the Wright Building to 504 Philtower, Tulsa, Oklahoma.

J. BOYD BEST, geologist with the Houston Pipe Line Company, read a paper on "Gas Sands in South Texas," before the annual meeting of the Natural Gas Department of the American Gas Association at Dallas, Texas, May 9.

The Panhandle Geological Society of Amarillo, Texas, has elected new officers as follows: president, JOHN L. FERGUSON, district geologist for the Amerada Petroleum Corporation; first vice-president, J. J. MAUCINI, of the Marland Production Company; second vice-president, L. M. OLES, Prairie Oil and Gas Company; and secretary-treasurer, LAWRENCE R. HAGY, of Hagy & Herrington.

F. B. PLUMMER, consulting geologist of Fort Worth, addressed the University Club of Fort Worth, Texas, May 11, on the subject, "The Relation of Production to Structure."

DJEVAD EYOUB, of the Empire Oil & Gas Company, was transferred on May 1 from Laredo, Texas, to the company's headquarters at Tampico, Mexico. His post office address is Apartado 1,388.

The American Association of State Geologists will take its annual field trip in Oklahoma, October 25, 26, and 27. The members are to attend the International Petroleum Exposition at Tulsa, which will be open October 20 to 29, inclusive.

FRANK C. GREENE, recently chief geologist of the Skelly Oil Company, resigned that position effective May 1 and is now engaged in research in stratigraphy in the geological department of the Roxana Petroleum Corporation at Tulsa, Oklahoma.

AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS

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Membership is restricted to members of the A.A.P.G. in good standing, residing in the Pacific Coast states. Dues of $2.00 per year are payable to the secretary-treasurer of the Pacific Coast Section. Members of the A.A.P.G. transferring to the Pacific Coast are cordially invited to become affiliated with the local section, and to communicate their change of address promptly to the secretary-treasurer of the Pacific Section.

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